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Role of Mortgage Backed Securities in a Diversified Portfolio under the Mean-Variance framework

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Glossary

A.I.G.	American Insurance Group
ABS	Asset backed securities
ARM	Adjustable rate mortgages
BofA	Bank of America
CAL	Capital allocation line
CDO	Collateralized debt obligations
CDS	Credit default swaps
CMBS	Commercial mortgage backed securities
CMO	Collateralized mortgage obligations
DCF	Discounted Cash Flow
ETF	Exchange Traded Fund
Fannie Mae	Federal National Mortgage Association
FED	U.S. Federal Reserve System
FFO	Funds From Operations
Freddie Mac	Federal Home Loan Mortgage Corporation
GAAP	Generally Accepted Accounting Principles
Ginnie Mae	Government National Mortgage Association
GMV	Global minimum- variance portfolio
GSE	Government sponsored enterprises
IPO	Initial Public Offering
LIBOR	London Interbank Offered Rate
NAREIT	National Association of Real Estate Investment Trusts
NAV	Net asset value
NCREIF	National Council of Real Estate Investment Fiduciaries
PAC	Planned amortization class
REIT	Real Estate Investment Trust
RMBS	Residential mortgage backed securities
RTC	Resolution Trust Corporation
S&P	Standard and Poor’s
SEC	U.S. Securities and Exchange Commission
TRS	Taxable REIT subsidiary
US	United States of America
YTM	Yield to maturity

Abstract

In light of the negative reputation of mortgage backed securities (MBS) due to the subprime crisis and considering the swift recovery of the US real estate market since the crisis, the role of MBS in a mean-variance optimized portfolio is assessed. Excellent diversification benefits as well as attractive risk/ return attributes of agency- MBS are discovered leading to persistently biased allocations towards agency-MBS in a mixed portfolio with equities, bonds, MBS as well as real estate indices and excellent diversification capabilities are revealed in mixed portfolios combining agency-MBS with direct real estate investments.

Keywords: Mortgage Backed Securities, Diversification, Portfolio Optimization, Real Estate Investments

1. Introduction

The Financial crisis in 2007 and 2008 created significant uncertainty about financial investments and lead governments to introduce substantial quantitative easing programs to lower inflation and provide liquidity in the markets. The resulting low interest rate environment lead to the hunt for yields of investors, since traditionally safe assets like treasury bills provided yields barely exceeding inflation rates. Alternative investments like commercial real estate benefitted tremendously from the low interest rates as the spreads between safe treasury bills and real estate investments widened. The debt side of real estate investments could not recover from the crisis as quickly and remained notorious for causing the financial crisis. Being true only for the subprime segments of the mortgage backed securities (MBS), the substantially larger market for US government agency-guaranteed MBS offers securities with higher yields than treasuries at comparable risk exposure. These agency-MBS held up well during the crisis and account for around a quarter of the US fixed income market in 2017. The current change of the low- interest environment in the US, due to reducing of quantitative easing measures and a growing economy, may lead to shrinking spreads, which increases demand for inflation protected assets like MBS. This fosters the attractiveness of adding mortgage backed securities to a diversified investment portfolio as an addition to equities, bonds as well as real estate. For the consideration of assets to a mixed portfolio, investors analyze the risk and return attributes as well as the diversification effects on the portfolio. A widely used tool for calculating the optimal asset weights of a mixed portfolio, is the mean-variance analysis first proposed by Harry M. Markowitz in 1952.

In light of the current market environment and the lack of recent research about MBS allocations in mixed investment portfolios, the following research question is formulated. Are mortgage backed securities a valid financial instrument in a diversified portfolio, including stocks and bonds

as well as conventional real estate investment instruments? The following research hypotheses are tested in an empirical framework using quantitative time-series data for the last 18 years from the Bloomberg Terminal on ten indices, representing segments of the asset classes equities, treasuries, corporate bonds, MBS, structured mortgage securities as well as real estate. This data is analyzed in the mean-variance optimization framework in order to identify allocation patterns and assess the importance of the individual asset classes in optimized portfolios. First, it is hypothesized, that agency-MBS have substantial allocations in mean-variance optimized portfolios due to attractive the risk/return attributes. Secondly, it is hypothesized, that the riskier MBS segments have lower allocations than agency MBS due to the effects of the financial crisis. Finally, it is hypothesized, that allocations to real estate investment vehicles are larger than agency- MBS at higher risk levels, due to the strong and persistent recovery since the financial crisis.

This work is structured as follows. The literature review analyzes existing research and provides an overview about the mean- variance framework, focusing on theoretical implications of the diversification effect and the most important limitations of this concept. In the next section, the asset classes available to investors are discussed focusing on equities, conventional fixed income instruments like treasury and corporate bonds as well as real estate investment instruments like real estate investment trusts and direct real estate. Further detail is provided on the differences between direct and indirect real estate. The last part of the literature review is focused on the description of securitized mortgage instruments and their role during the financial crisis. The third chapter is concerned with data analysis. In the first section, an overview of the market for financial assets is provided with a focus on the performance and market characteristics of the securitized mortgage market and the real estate market during the last two decades. The next section is the methodology, where a theoretical basis is provided for the mean-variance optimization followed by an

explanation of the asset allocation model created in Microsoft Excel, used for the mean-variance analysis. It follows a description of the ten indices that were retrieved from Bloomberg in order to be used for the portfolio optimization. The subsequent section analyses the returns of the previously described indices with descriptive statistics as well as a correlation analysis. These measures provide the basis for the mean-variance optimization conducted in section 3.4. Multiple portfolio optimizations with several scenarios are conducted in order to understand the behavior of mortgage backed securities in mean-variance optimized portfolios. The last chapter first discusses and interprets the results of the previously conducted optimizations and finishes with a conclusion and a discussion of the limitations of this study as well as recommendations for further research.

2. Literature Review

The literature review begins with an analysis of the mean- variance framework followed by an examination of financial assets. Subsequently, direct and indirect real estate investments are discussed in further detail. The final part of this chapter focuses on a detailed analysis of securitized mortgage vehicles and their role during the financial crisis.

2.1. Theory of the Mean-Variance Optimization

Investors have access to a variety of investment assets to include in their portfolio which may vary depending on several key attributes like risk/return characteristics, liquidity and diversification potential. Liquidity refers to the effort and speed required to exchange the value of an asset for cash (Bodie, Kane, & Marcus, 2014). Diversification plays a significant role for investors as it allows for portfolio risk reduction when combining assets that do not have a perfect positive linear relationship. The linear relationship between assets is called correlation. Correlations are measured by the Pearson correlation coefficient and refer to the degree of co-movement between two assets. The coefficient ranges from positive one, indicating a perfect positive correlation, over zero, indicating no correlation to negative one, indicating a perfect negative or inverse relation. The diversification effect on portfolios will be examined in greater detail in section 3.2.1. A significant part of financial research focuses on the optimal asset selection and asset management of mixed portfolios, ranging from equal weighted or risk weighted portfolios to more complex techniques. Decisions are “made about when to make any adjustments as a consequence of a changing economic environment or requirements, decisions that are often complicated by consideration of taxes and costs” (Shipway, 2009). A famous asset selection technique is the is the mean- variance analysis first developed in the Modern Portfolio Theory by Harry M. Markowitz in 1952. This approach is based on the assumption, that all investors are rationale and risk averse. Rationale

investors only focus on the financial attributes of their investments and risk aversion refers to the preference of the least risky investment given the same return and all else equal. The mean-variance analysis is a "mathematical framework for mixing investments within a portfolio to calculate the expected returns for any given level of risk" (Shipway, 2009).

In mean-variance optimization, the weights of the assets to be included in an investment portfolio are assessed by their relative risk and return attributes. The risk is represented by the asset's standard deviation and correlation to the other assets in the portfolio. A mean-variance optimized portfolio will offer the highest level of return for each level of risk (S. Lee & Stevenson, 2005). Hence, selecting assets with diversification potential results "in an ability to construct a portfolio that had the same expected return and less risk than a portfolio constructed by ignoring the interactions between securities" (Elton & Gruber, 1997). Mean-variance optimization allows for the calculation of two essential portfolios for investors. The first portfolio is the tangency portfolio, which maximizes the portfolio Sharpe Ratio, which indicates the return per unit of risk. The second portfolio is the minimum-variance portfolio, which minimizes portfolio variance, ignoring portfolio returns. As the optimization process only focuses on the excess return and risk of a portfolio, the tangency portfolio may allocate extreme weights to certain assets, while excluding others. In order to control for extreme allocations, Byrne and Lee (1995) propose placing upper and lower bounds as constraints on the weights of each asset. This approach restricts exclusions or extreme allocations. There is substantial evidence in financial literature, that variances are more persistent throughout time than returns, thus the minimum variance portfolio is proven to be a better portfolio choice in an out of sample environment than the mean-variance optimized portfolio (Stevenson, 2001). The methodology of mean-variance optimization will discussed in detail in section 3.2.3.

The most significant limitation of the Modern Portfolio Theory is that calculations are based on historical data. Changing key return characteristics, in particular the time-varying correlations between asset classes indicate significantly changing optimal portfolios throughout an investment horizon. Hence, a portfolio allocation calculated through the mean-variance framework may only represent an optimal allocation for the analyzed sample period, while other sample periods could render different allocations due to changes in risk return characteristics. The same is true for an out of sample environment (S. Lee & Stevenson, 2005). There is a large amount of literature concerning the time-varying correlations between asset types as well as international diversification. Researchers have found strong evidence for increasing correlations during recessions. Especially during the financial crisis, correlations between asset classes increased, which drastically reduced diversification potential. Nevertheless, Asness et all (2011), find evidence for long term diversification benefits and highlight that “short, systemic crashes” cannot be prevented by diversification but do not invalidate the strategy. Correlations increase during crashes in line with an increase in volatility, for example the volatiliy indicator for the S&P 500, VIX had a ninefold increase at the peak of the crisis (Loviscek & Riley, 2013), which may serve as an indicator for market disturbances. The financial crisis of 2007 and 2008 will be discussed in greater detail in section 2.5. Next to time-varying correlations, there is evidence for increasing correlations across asset classes since the early 2000s, leading to less diversification potential and effectiveness of portfolio optimization. Reasons for this phenomenon may be the increased effciency and the growing gloablization of financial markets (Kolanovic, 2011). Further studies found evidence for an inverse relationship between correlations among asset classes and the state of the economy. For example Michel et al (2015) found evidence for increasing correlations between the S&P 500 and fixed income indices during poor market performance and lower

correlation during bullish and normal markets. This finding indicates, that a combination of equities and debt securities would offer diversification benefits during a healthy economy but would incur substantial losses during market crashes. In conclusion, the essential objective of diversification, to reduce risk and hedge against losses of certain assets does not hold during distressed periods where it is most needed.

2.2. Asset Classes

Investors have a variety of choices to invest their wealth and due to the concept of investor heterogeneity, various investment opportunities with differing risk/return characteristics exist to serve their investment criteriums. Hence, investors may range from individual investors with very limited funds to invest and high-risk aversion to large institutional investors like yield seeking hedge funds. There are two broad categories of assets, that investors can place their wealth in, real assets and financial assets. Real assets include the goods and services in an economy, which may be real estate, commodities, machines and other assets. Of these, purchases of commodities on specific exchanges and the acquisition of a property, also referred to as private or direct real estate investment, is a common real asset investment for investors. An analysis of the real estate market is provided in the section 2.3.

2.2.1. Financial Assets

Financial assets refer to various types of securities, which can be categorized into equity, fixed income and derivatives. These asset classes can be broken down into further categories and subcategories in order to create groups of securities with similar characteristics. Characteristics may be for example the behavior in the capital markets, risk or liquidity. Besides a classification of asset classes into financial assets and real assets, there is another traditional classification system, which overlaps with the one previously described. Here, assets are divided into four major asset

classes, namely cash, stocks, bonds and real estate. This system is simplified and does not include asset classes like derivatives. The following section will provide a brief overview of the different financial asset types and reviews corresponding literature concerning diversification potential and their role in mixed portfolios.

The equities asset class refers to publicly traded firms who sell ownership shares on stock exchanges. Equities, also referred to as common stock, entitle the shareholder to voting rights and possibly dividends. Hence, this asset class is characterized by an uncertain payment stream resulting from dividends and capital gain when selling the shares at a premium to the purchase price. Stock prices reflect investors collective assessment for a firm's current performance and future prospects. In case of a bankruptcy the value of the shares may become worthless, thus the shareholder bears the business risk. (Bodie et al., 2014). Hence, for assessing the share price of a firm, a company valuation is often conducted, that includes future growth prospects and the underlying risks of future cash flows. The most commonly quoted equity index in the US is the S&P 500, which is often used as a benchmark for equities. The S&P 500 index contains publicly traded corporations from a variety of sectors. The correlations between these firms also varies strongly, thus equity investors build portfolios with stocks that offer diversification benefits. However, the study from Loviscek and Riley (2013) estimated an increase in firm-level correlation in the S&P 500 of 75% during the financial crisis, indicating a systematic crash that decreased diversification capabilities and could not prevent substantial losses. In fact, the market capitalization of the US stock market dropped by more than 50% during the financial crisis.

In contrast to the equity asset class, fixed income securities provide a fixed cash flow to investors. There are two general fixed income categories, money market securities and capital market

securities. Money market securities include debt securities with short maturities, high liquidity and low risk like US Treasury bills or Certificates of Deposit of large banks with maturities of less than a year. Certificates of deposit are deposits at banks which cannot be withdrawn and the payout takes place at maturity, Treasury bills are a major instrument for the US government to raise money and these securities are backed by the US Treasury, which is considered to be free of default risk. Hence, Treasury bills are commonly used as a proxy for risk-free assets. Capital market securities have a variety of forms and have vastly heterogenous characteristics in terms of maturity, liquidity, cash flow pattern as well as risk and return attributes. Examples for capital market debt securities are corporate bonds, Treasury bonds, mortgage securities and bonds issued by federal agencies and municipalities. The income of these debt securities is generally fixed or defined by a formula leading to specified cash flows for the bond investors (Bodie et al., 2014). Treasury bonds are issued by the US Treasury and backed by the Treasury, similar to Treasury bills. The income Treasury bond investors receive are fixed coupon payments at a specific interest rate and frequency as well as the face value of the bond at maturity. The discount rate for assessing bonds is called the yield to maturity (YTM) and depends on the risk of the bond. The main risk for bonds is the default risk of the bond issuer, which creates uncertainty about the payment of coupons and repayment of the face value. The default risk is particularly important for corporate bonds and investors typically assess the default risk through the issuer's credit rating. Financial assets are commonly rated by the large American rating agencies Standard & Poor's, Moody's and Fitch. These ratings are used to "measure the ability of issuers to meet their future financial commitments, such as principal or interest payments" (Coval, Jurek, & Stafford, 2009). Investment grade ratings range from AAA to BBB- or equivalent, depending on the rating institution. Corporate bonds are a common instrument for firms to raise capital in the capital markets and its structure is similar to Treasury bonds. However, there are special types of corporate bonds, like secured and unsecured bonds, depending

on whether a collateral is backing the security in case of bankruptcy. Additionally, there are callable bonds, where the bond issuer has the right to repurchase the bond at a specified call price. Another major type of debt securities is federal agency debt. A large part of the mortgage securities falls under this category of fixed income, since federal agencies like the Federal National Mortgage Association issue mortgage backed securities backed by so called conforming mortgages. Mortgage backed securities, which are not issued by federal agencies due to nonconforming mortgages as collateral are called private label issued mortgages. Section 2.4 will discuss mortgage backed securities in greater detail.

The third type of financial asset are derivatives, which are contract based complex securities with payoffs depending on the prices of the underlying assets. The main objective of derivatives is risk hedging and risk transfer. Examples are call and put options, future contracts and swaps. Another example are credit default swaps, which play a substantial role for certain securitized mortgage instruments and are discussed in section 2.4.3.

2.3. Real Estate Investment Vehicles

Real estate as the fourth traditional asset class may either be a financial asset or a real asset, depending on the real estate investment vehicle. Private real estate is considered a real asset versus indirect vehicles as financial assets. This section briefly examines the different property types available for investors, followed by a short description of private real estate and a more detailed description of the real estate investment trust (REIT) market as an important indirect real estate vehicle.

2.3.1. Overview of the Real Estate Market

The main property types are residential, retail, office, industrial, hotel and specialty properties. Residential properties can be categorized into single family houses, apartments or multifamily buildings, as well as owner occupied or rental properties depending on the use of the property. Residential real estate primarily depends on the local population growth, employment and housing affordability. The owner-occupied housing depends strongly on the interest rate level since mortgages are commonly used for financing these properties. Retail properties are another major property type, which refer to retail stores, shops or shopping centers. These properties depend on disposable income levels and aggregate wealth of the targeted households as well as the local traffic volume. Office properties depend primarily on employment and office occupancy in the relevant market. The next property type is industrial properties, which also have a variety of sub-categories like factories, transportation properties or power plants. The demand for these assets depends on a variety of factors like employment in the specific segment, product demand and transportation volume. Industrial properties tend to have large investment volumes due their size and may only be suitable for direct investment for large institutional players. Hotel and convention properties mainly depend on leisure and business tourism numbers as well as air passenger volume. Additionally, there are specialty properties like leisure properties, for example theme parks or educational facilities like schools and universities (Geltner, Miller, Clayton, & Eichholtz, 2006). In theory, all property types could be invested in through both direct and indirect real estate investment vehicles, however, some property types may be more suitable than others for a certain vehicle. A major limiting factor for direct real estate is the indivisibility of the properties leading to large minimum investment volumes, thus shopping centers, industrial and large office or hotel properties may be less suitable for this vehicle.

2.3.2. Direct Real Estate Investments

As stated above, private real estate is considered as a real asset and thus has substantial differences compared to financial assets. In contrast to financial assets, private real estate assets are not traded on exchanges and are highly heterogenous assets as each property has to be assessed individually. Private real estate is characterized by high capital requirements due to the direct acquisition of properties, low liquidity due to legal procedures for acquiring or selling properties and finding a counterparty that accepts the perceived adequate price. The last issue leads to another important aspect regarding direct real estate, which is the information inefficiency on transactions. Direct property transactions suffer from inaccuracy due to the uniqueness of properties, the lack of sale frequency and transaction repetition as well as the fact that sales only represent "the agreement of two parties, not a broad market consensus" (Geltner et al., 2006). Additionally, substantial transaction costs caused by legal and brokerage fees as well as taxes occur during real estate transactions In order to mitigate the high capital requirements on property types like large retail or hospitality assets, partnerships between investors can made in order to pool capital to jointly acquire an asset (Brueggeman & Fisher, 2011). Nevertheless, direct real estate investment may benefit from a low correlation to financial assets, hence offering better protection against shocks in the market. Another advantage of private real estate are the potentially higher yields, since no management fees are paid and substantial tax benefits arise due to write off possibilities of mortgage debt as well as depreciation expenses. The valuation of private real estate depends on the property types, however most commercial properties are valued with the discounted cash flow (DCF) approach and owner-occupied housing through the comparison approach where current values of similar houses are adjusted to the subject property.

2.3.3. Real Estate Investment Trusts

Next to direct real estate investments there are multiple vehicles for investing in indirect real estate. One of the largest indirect vehicles are Real Estate Investment Trusts (REITs), which are traded on stock exchanges and offer the liquidity and information advantages of traded companies. REITs offer the possibility of investing in a diversified real estate portfolio through a liquid instrument with small minimum investment volumes. These companies can be considered as the equity side of the public commercial real estate market compared to the debt side represented by commercial mortgage backed securities. Essentially, REITs are publicly traded companies that focus on real estate investments, which must qualify, through several requirements or tests, for corporate income tax exemption. An example for a private indirect vehicle for investing in real estate are private real estate investment funds. These vehicles offer increased liquidity, smaller minimum investments as well as more diversification as direct real estate investments. However, the liquidity of public real estate investments is not matched and prices of real estate funds or corresponding indices are based on appraisals which are subject to bias and inaccuracy (Lizieri, 2013). This study will focus on REITs as an indirect real estate investment vehicle.

REITs were created in the 1960s as part of the Real Estate Investment Trust Act, which allowed the pass-through structure of eligible real estate companies. This structure avoids double taxation, since earnings are only taxed at the individual shareholder's personal income tax level. There are certain tests that REITs continuously have to meet, which are designed to "maintain REITs as somewhat passive investment vehicle, not too far removed from the original 'mutual fund for real estate' idea, and also to ensure that REIT investment is accessible to small individual investors"(Geltner et al., 2006). These requirements promote free-float, largely limit a REIT's income to real estate assets and require substantial dividend distributions of the net income. REITs

are assessed similar to other traded firms by discounting expected future cash flows, however, due to the required focus on real estate assets, the value of the underlying properties plays a dominant role and are considered through the net asset value (NAV). The net asset value refers to the estimated current value of the assets owned by the REIT, deducted by the total liabilities (Brueggeman & Fisher, 2011). For the valuation of REITs, real estate fundamentals are combined with stock fundamentals. The key value drivers for REITs are the cash flows distributable to shareholders, the growth of the cash flows as well as the growth of the net asset value. The risk is reflected in the discount rate and reduces the value accordingly. REITs characteristically are highly levered, which is a main factor for the typically high levels of systematic risk for REITs. Nevertheless, Brounen and Koining (2012) discover lower volatility of REITs compared to the overall stock market. A REIT's cash flows are measured in Funds From Operations (FFO), which is an earnings measure deviating from the Generally Accepted Accounting Principles (GAAP) Net Income. FFO is calculated by adjusting the GAAP Net Income by adding the real estate depreciation and amortization expense as well as the preferred stock dividends and subtracting the net gains from property sales and extraordinary items (Geltner et al., 2006). Typically, REIT stocks can be considered as income stocks due to the high dividend payout ratio required for the REIT status. Hence, these companies cannot retain large amounts of earnings for profitable investments, which lead to growth in the firm. Possibilities for growth is the purchase of properties and expected future growth through attractive development possibilities of existing land or development rights (Geltner et al., 2006).

The market for REITs surged during the REIT IPO boom during 1993 and 1994, raising USD 16.5 billion, followed by a surge in secondary offerings in 1997 and 1998, raising additional USD 32 billion. During this bullish period for REITs, share prices for REITs soared, while real estate prices

remained relatively stable indicating an overvaluation of REIT stocks. In 1999 and 2000, the REIT market crashed due to a substantial loss in confidence in the REIT sector caused by the disconnection between real estate prices and REIT shares (Geltner et al., 2006). During the early 2000s, after the dot com crash, the REIT market stabilized and prices soared in line with the general stock market. During the financial crisis, property prices plummeted and the cost of debt surged, leading to a strong decline in the REIT market.

In conclusion, REITs offer more liquidity, property as well as market diversification potential, information efficiency and lower minimum capital requirements than direct real estate investments. Direct property offers potentially higher yields and substantial independence from financial markets (Geltner et al., 2006).

2.3.4. Diversification Potential and Limitation of Real Estate Investments

According to Lizieri (2013), reasons to include real estate in a diversified portfolio include "favorable risk-adjusted returns, inflation hedging qualities, and the benefits of diversification". Hence, correlations between property returns and financial assets are expected to be low in order to qualify as an asset class with strong diversification capabilities. When considering direct real estate in a mean-variance optimization framework, several characteristics of this asset class may impose issues regarding the resulting portfolios. The indivisibility aspect and heterogenic lot sizes between different property types like apartments or shopping centers, creates significant hurdles for the optimization framework as the calculated weights may not be achievable. Indirect real estate investments like REITs do not suffer from these limitations and target allocations could be matched more easily. This issue is also true for other common allocation strategies like equal weight or risk parity portfolios. Another issue regarding direct property are appraisal based direct property returns,

which have a volatility smoothing characteristic that overstates the attractivity of this asset class and may create dominant weights in a mean- variance optimization. Hence, total return and non-appraisal based indices should be considered for evaluating the allocation to direct real estate (Lizieri, 2013). As described above, the low correlation to equity markets and attractive risk and return attributes lead to high allocations of real estate in mean- variance optimized portfolios. Nevertheless, there is evidence for a lower asset allocation to real estate in investment portfolios than predicted by optimized portfolios amounting to 20 to 30% (Brounen, Prado, & Verbeek, 2010). According to Brounen, Prado and Verbeek (2010), direct real estate offers short term inflation hedging benefits when accounting for interest rate risk, however, "over longer holding periods real estate proves to be a poor interest rate and particularly poor inflation hedge". Similar to direct real estate, they find evidence for diversification potential and attractive risk reward characteristics for indirect real estate, though no significant inflation hedging capabilities. Additionally, the study found an increasing allocation to indirect real estate in efficient portfolios with higher risk tolerance that goes in line with a decrease in direct real estate allocation (Brounen et al., 2010).

2.3.5. Real Estate During the Financial Crisis

According to Lizieri (2013), real estate assets could not provide the diversification and hedging attributes previously anticipated during the financial crisis. Property returns were expected to "insulate the portfolio against drawdown during bear markets" (Lizieri, 2013). However, during the crisis, property returns plummeted throughout property types and markets. Moreover, evidence was found for increasing correlations of real estate to financial assets during the crisis. This indicates the time-varying correlation of real estate to equity markets. In fact, Lizieri (2013) found evidence for time-varying correlations of both private and public real estate to financial assets, which peaked during bear periods of the stock market. Hence, the promised insulation against a

drawdown did not become true since the diversification benefits weakened during the critical periods. During bullish periods, correlations between private real estate and financial assets were found to be low indicating diversification benefits, though this relationship diminished during the crisis, which was caused by market illiquidity and inaccurate appraisals due to lags and asymmetric market information. The findings of Lizieri (2013) are evidence against the attributes discovered by Hudson-Wilson et al. (2003) and Chun et al. (2004), who suggested strong hedging capabilities due to pay-offs during bear markets.

2.4. Mortgage Backed Securities

Mortgage backed securities are an essential part of the US fixed income market, accounting for around 25%. MBS have unique risk/return characteristics, differentiating this asset class from other debt instruments. MBS are fixed income securities, which have a pool of home or commercial mortgages as a collateral. This section begins with a detailed overview of mortgage backed securities, continuing with the history of MBS, followed by a brief explanation of the valuation methods for MBS. Subsequently, structured mortgage instruments are analyzed and the remainder of the section is focused on the financial crisis, focusing on the role of MBS and rating agencies.

2.4.1. Overview and Origin of Mortgage Backed Securities

There are two major types of mortgage backed securities, depending on the underlying collateral of the mortgage. The first type of MBS are residential mortgage backed securities (RMBS), which refer to pools of mortgages taken on by homeowners to finance the acquisition of their homes. The second type are commercial mortgage backed securities (CMBS), which refer to “debt instruments collateralized by non-recourse loans which are secured by commercial real estate”, usually

apartment properties, retail centers, hotels, restaurants, warehouses and office buildings (Maxam & Fisher, 2001).

The market for mortgages originates in the provision of long-term loans to homebuyers by local saving banks, which receive a pledge on the property as the collateral. For homeowners to be eligible for a mortgage, certain criteria had to be met by the potential borrower in terms of stable income history, documentation and other criteria. According to the terms of the loan, the borrower provides frequent payments to the originator including the interest payments as well as amortization payments, which reduce the remaining loan amount (Fabozzi, 2005). The general level of interest rates for mortgages depends on the interest environment of the economy, similar to treasury bonds. The characteristics of the interest payments differs, depending on the loan type as well as maturity and are specified during the closing of the loan. There are fixed rate mortgages and those with variable interest rates, the so- called adjustable rate mortgages (ARM), which are linked to a market rate index. Some ARM loans start with lower initial interest rates that subsequently rise to a fixed spread over the specified index (Fabozzi, 2005). These types of loans played a particularly important role during the financial crisis, which will be discussed in greater detail in section 2.5. The term for mortgages usually amounts to either 15 or 30 years. An important aspect of mortgages is, that homeowners have the right to prepay their mortgages with additional amortization payments. This leads to uncertainty with regards to the maturity of the mortgage, since it could be repaid at any time during the term.

In order to increase the supply of loans, bankers made use of securitization, where mortgages were bundled into pools, which could be traded as financial assets and had a high demand in the financial markets. (Bodie et al., 2014). These financial assets are referred to as mortgage-pass-through

securities and are treated as fixed income securities. The cash flows of these securities are passed through to the MBS investor and consist of the interest-and amortization payments as well as the prepayments from the borrowers. There are two types of mortgage pass-through securities, agency pass-through securities and nonagency or private label pass-through securities. The first type of securities are mortgage pools with a credit guarantee provided by government sponsored enterprises (GSEs). There are three GSEs, Government National Mortgage Association (Ginnie Mae), the Federal National Mortgage Association (Fannie Mae) or the Federal Home Loan Mortgage Corporation (Freddie Mac). During the peak of the financial crisis, on September 6, 2008 Fannie Mae and Freddie Mac were placed into conservatorship of the Federal Housing and Finance Agency in order to be backed by the full faith of the US Department of Treasury "to provide financial support […] to continue to provide liquidity and stability to the mortgage market" (Federal Housing Finance Agency, 2008). Hence, all three agencies are backed by the US Department of Treasury since Ginnie Mae has already been a government agency before the financial crisis. The second type are mortgage pools that are not guaranteed by a GSE, but by private firms, like commercial banks or thrifts, and thus may have some degree of credit risk in the insurance (Fabozzi, 2005). For loans to qualify as an agency loan, particular requirements in terms of borrower credit worthiness as well as loan size have to be met. For example, the agencies state loan size limits, thus more expensive properties often do not qualify for the agency loans and are referred to as jumbo loans. Chart 1 displays the pass-through structure of MBS. The loan originators sell the conforming mortgages for a premium to financial institutions like Fannie Mae and Freddie Mac and may continue to collect the interest (I) and amortization (P) of the homeowners for a service fee and transfer it to the mortgage pool. The mortgage pool is securitized into a MBS by the financial institution and subsequently sold to investors who will receive the payments of the homeowners. Guaranty institutions like Fannie Mae and Freddie Mac further guarantee the default

and credit risk of the mortgages for a guarantee fee (Kariya & Kobayashi, 2000). This structure is called pass-throughs since the cash flows are passed through from the home owners to the final investor.

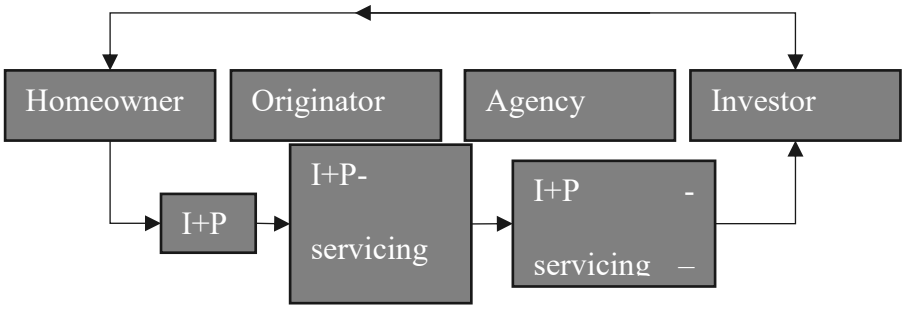

Chart 1: Cash Flows in a MBS, adopted from (Bodie et al., 2014)

The second type of RMBS are MBS with non-agency mortgages as collateral. These mortgages did not qualify the requirements for conforming mortgages due to a lack of credit worthiness of the borrower, unsupported type of property and other reasons. Non-agency MBS are characterized by an exposure to the default risk of the homeowner, since there are no guarantees on the cash flows. The market for non-agency MBS grew quickly between 2000 and 2006, reaching a 56% market share in MBS issuances in 2006 and more than USD 1 trillion in issuances. A market analysis of MBS issuances is provided in the market analysis in section 3.1.1.

The second category of MBS are CMBS, which have a substantially smaller market than RMBS but, similar to RMBS, were created to increase supply of commercial mortgages. In order to overcome the general issues of illiquidity of real estate investments, securitization as a tool for innovative financing is used. The income achieved through these products is characterized by the "receipt or payment of a predictable and dependable income streams i.e. rents or loan payment" (Solomon & McCluskey, 2010). Furthermore, CMBS are characterized by the non-recourse attribute, which refers to the concept, that in case of a borrower default, the lender has only access

to the proceeds from the sale of the underlying real estate as no guarantee is provided (Fabozzi, 2005). Further key differences between CMBS and RMBS are the preclusion of pre-payments, since these mortgage agreements either prohibit or penalize the refinancing. Secondly, there are no guarantees provided from government agencies like FNMA and GNMA to eliminate the credit risk, which leads to default risk of the borrower as the main pricing parameter for CMBS (Maxam & Fisher, 2001).

When comparing mortgage backed securities to the traditional fixed income securities in terms of key attributes, there are several differences that potentially render MBS investments more attractive than other fixed income securities. The main risk of corporate bonds is the credit risk of the issuing company. If the company is unable to pay the promised coupon or face value, the bond holder incurs losses. The riskiness of the repayment is represented in the discount rate used for pricing the bond. Agency- MBS do not have credit risk, since their coupon and principal payments are guaranteed by the US Department of Treasuries. Non- agency- MBS are subject to similar credit risk as corporate bonds or government bonds. However, instead of credit risk, agency- MBS are exposed to prepayment risk since the mortgage holders have the option to prepay their mortgages leading to losses for mortgage investors. The homeowners have an incentive for repayment in case of falling interest rates as they can refinance their mortgages cheaper with the lower interest rates. Since the mortgage investors expect a certain rate of prepayment, less prepayment than expected, caused by rising interest rates, may also lead to an extension risk. In this scenario, MBS investors receive less prepayments than expected and can invest less funds in the attractive high interest rate environment. Thus, the prepayment and extension risk renders MBS cash flows more uncertain. Fixed coupon bonds, on the contrary have fixed coupon payments, that are only subject to the described credit risk and interest rate risk (Rowley Jr., 2013).

2.4.2. Valuation of Mortgage Backed Securities

As mentioned above, homeowners have the right to prepay their mortgages at any time, which creates a prepayment risk in addition to the interest rate risk for the MBS investor (Kariya & Kobayashi, 2000). The prepayment behavior of homeowners is heterogenic and depends on economic as well as noneconomic reasons rendering MBS valuation highly complex. Prepayments may occur due to refinancing, the sale of the property or due to the default of the borrower. A refinancing incentive arises when the current interest rate for mortgages drops abruptly below the initial contracted mortgage rate (Kariya & Kobayashi, 2000). In case of declined mortgage rates, it may be profitable for the homeowner to take on a new, cheaper loan and paying off the initial mortgage with the proceeds. Incentives for selling the house may be economic or noneconomic. Noneconomic or personal reasons could be changes in personal circumstances like family or employment. Economic circumstances refer to profitable opportunities for selling the house, since the value of the house appreciated. The prepayment rates due to selling the house, in particular due to personal reasons, are difficult to estimate due to the lack of reliable information. Economic and demographic variables are commonly used for estimating prepayments. The prepayment option of borrowers can be compared to a callable bond, where the bond issuer has the right of calling the bond. In this case, the borrower can call or in this case prepay the loan at the remaining loan balance. When disregarding the non-interest rate related incentives for repayment of the loan, the value of a MBS depends largely on the interest rate since the principle value decreases in line with the interest rate (Bodie et al., 2014).

In 2006, the government- sponsored enterprises (GSE) held credit guarantees for nearly 50% of all outstanding residential mortgages in the US, indicating their importance for a functioning market

(Downing, Jaffee, Wallace, Mae, & Mac, 2009). Hence, the default risk for GSE backed RMBS could be neglected due to the guarantees and the single determining risk factor for RMBS was the prepayment risk. The GSEs would repay the principle of the mortgage in case of the default of the borrower, in return, during the pass-through process of the mortgage, a fee for the GSE is deducted. The prepayment characteristics of MBS makes its valuation complex since the maturity of the mortgages included in the MBS depend on the prepayments of the mortgages. The value of a MBS can be decomposed into a riskless bond (due to the guarantee provided by the guaranty institution) and the prepayment option (Kariya, Ushiyama, & Pliska, 2011). This option represents a significant risk for the value of a MBS portfolio and "depending on the interest rate environment, prepayment can either hurt or benefit the MBS investor" (Gabaix, Krishnamurthy, & Vigneron, 2007). Prepayments rates due to reasons other than refinancing can be combined to turnover rates which include prepayments due to the sale of houses, property destruction, borrower default and partial prepayment. When homeowners prepay their mortgages early, mortgage investors lose the interest income receivable in the future, hence early repayment or prepayment is not desired by investors. As discussed, homeowners have various reasons for repayment, thus part of the mortgages may be expected to be repaid constantly throughout the term of the mortgage pool. This turnover rate tends to be relatively stable and is primarily influenced by the "levels of real estate appreciation and home resale values" (Fabozzi, 2005). Informed, rationale investors may be referred to as efficient investors, who prepay when mortgage interest rates drop or property prices rise (M. Lee & Pace, 2006). This relationship indicates, that the more inefficient the homeowners of the mortgage pool are, the higher is the value of the underlying mortgages, since more mortgages are held until maturity (Downing et al., 2009). In case of a rationale investor, the mortgage holder "has a high-yielding asset payoff" when interest rates dropped, leading to the inability to reinvest the proceeds at a similar rate (Fabozzi, 2005).

The value of a MBS follows the concept of negative convexity, when interest rates decline, the value of the MBS decreases due to prepayments and when rates increase, the value of the mortgage pool decreases due to duration effects. Duration refers to the "weighted average time (in years) until the bond's future cash flows will be received. The weighting is proportional to the component of each future cash flow in the present value of the bond" (Geltner et al., 2006). In contrast to straight bonds, the MBS price has no linear relationship with the interest rate, instead, less appreciation due to declined interest rate and more depreciation due to duration as well as extension effects can be observed. This underperformance of MBS is compensated by higher base yields than comparable bonds (Fabozzi, 2005). The negative convexity characteristic of MBS can be seen in chart 2.

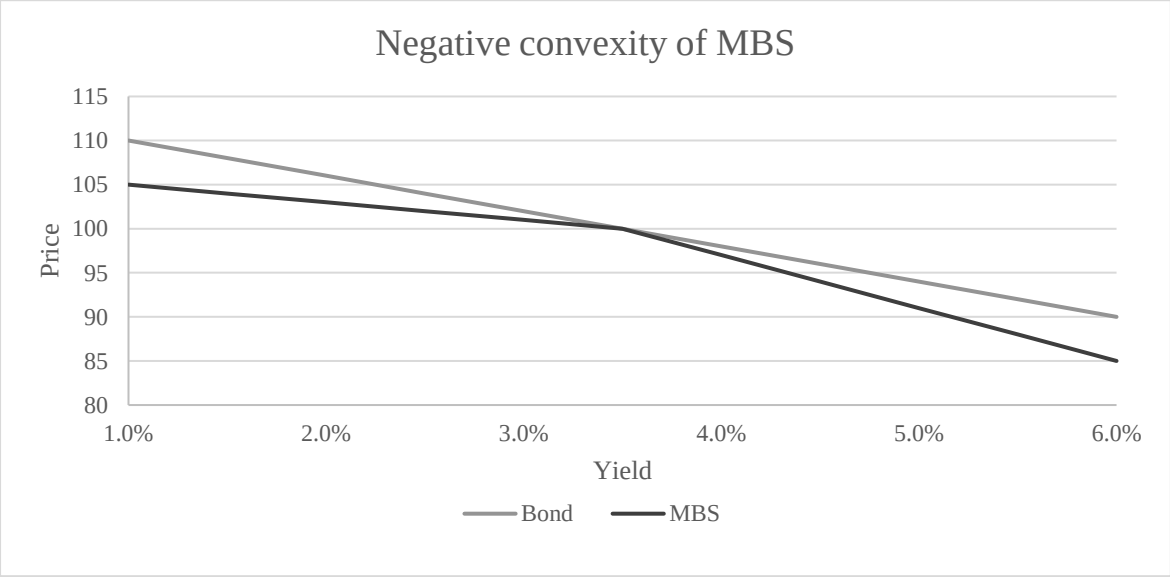

Chart 2: Negative convexity, adopted from Fabozzi (2005)

There are multiple approaches for valuing the prepayment option. A widely used model is considering the prepayment option as a call option on the underlying mortgage (Schwartz & Torous, 1989). Thus, when homeowners exercise their prepayment option out of the money due to personal reasons or cost constrains, the value of the mortgage increases for investors. Kariya, Ushiyama and Pliska (2011) propose a three-factor pricing model based on the research of Kariya and Kobayashi (2000), using the mortgage rate as the discount factor and breaking down the prepayment option into two factors, the prepayment due to refinancing or due to selling the property. However, this two-factor approach ignores the noneconomic incentives described above. Hence, a complete model for valuing MBS would require further factors for which accurate data is not available. A possible factor could analyze the positive difference between the property value and the loan size which correlates with the default rate. Additionally, a factor could be related to the availability of credit which depends on rising housing prices since higher valued houses indicate larger collaterals for the lenders leading to less restrictive lending standards. These inefficiencies in MBS pricing, may have played a role during the subprime crisis, since a more complete MBS pricing model may have been capable of giving warning signals before the sub-prime crisis (Kariya et al., 2011).

The valuation of CMBS is less complex than of RMBS, since prepayments are prohibited. Valuing CMBS depends on two components, a straight bond and the option to default, which indicates the difference to RMBS, which have the option to repay. Defaulting on a mortgage is strictly economic decision, which renders the valuation of CMBS less complex compared to RMBS, since only market parameters are used for estimating the default instead of a combination of personal and economic factors which is the case for RMBS (Maxam & Fisher, 2001). The main parameters affecting the defaults are the property value, the mortgage value and the income received from the properties. In their study, Maxam and Fisher (2001) found that due to the less systematic nature of

defaults than pre-payments, “CMBS exhibit much more stable cash flows […] and hence less reinvestment risk than residential MBS”.

2.4.3. Overview of Structured Mortgage Instruments

In this sub-section, the market for structure mortgage instruments is described, which are financial products, that repackage a portfolio of mortgages into segments with specific attributes which may be attractive to certain investors that are willing to pay a premium for these. Structured finance instruments refer to financial products, where cash flow generating assets like bonds, various types of loans as well as mortgages are pooled together and “prioritized capital structure[s] of claims, known as tranches, against these collateral pools” are created (Coval et al., 2009). Examples of structured finance instruments are collateralized debt obligations (CDOs) and collateralized mortgage obligations (CMOs. Collateralized debt obligations are repackaged pools of cash flow generating assets, which have mortgages, loans or bonds as collateral. CDOs can take various forms depending on the cash generating asset and underlying collateral. Collateralized loan obligations include loans as collateral and generate income through the debt service of the loans. A more complex type of CDOs are Synthetic CDOs, which have credit default swaps (CDS) as collateral. CDS are used to separate the credit risk from the corresponding asset and work similar to an insurance for the CDS purchaser. The synthetic CDO generates cash flow through the fees from the credit protection purchasers and distributes these fees in tranches to the CDO investors. However, in the event that a “defined credit event occurs on those reference assets, the CDO receives a payment from its investors and makes a payment to the counterparties that have bought credit protection from the CDO” (Fabozzi, 2005)

Collateralized mortgage obligations (CMO) are a form of collateralized debt obligations, which use mortgage pools as the underlying collateral. These products were initially engineered during the years before the financial crisis with the purpose of generating more profits in the booming market (Mackenzie, 2011). Most CMOs are created from agency pass through mortgage pools and hence contain homogenous high-quality mortgage pools. The CMO repackages the cash flows received from underlying mortgage pools into tranches according to investor preferences. Tranches may vary according to the prepayment exposure; common types are sequential and planned amortization class tranches. Sequential tranches may be structured to first receive prepayments to shorten the duration or planned amortization class (PAC) tranches which receive prescheduled cash flows independent of the underlying mortgage pool. Additionally, tranches are created to modify the interest payments. CDOs create floater and inverse Floaters, which change the fixed interest payments of the underlying mortgages to variable ones, that are linked to interest rate indices like the London Interbank Offered Rate (LIBOR). The floater would move in line with the LIBOR rate, while the inverse Floater has an inverse exposure to interest rate movements. Finally, there are altered versions of these tranche types to replicate certain characteristics and exposures that are attractive to certain investors (Fabozzi, 2005). Besides the agency CMOs, there is a market for non-agency CMOs which substantially benefit from the credit enhancement possibilities CMOs offer. Non-conforming loans like jumbo loans or subprime/ Alt-A mortgage pools are commonly repackaged to non-agency CMOs. These mortgage pools are exposed to default risk and the prepayment behavior may be more heterogeneous compared to agency MBS pools.

In structured finance products, a prioritization scheme is created in order to structure the claims of the cash flows of the underlying asset pool according to different risk/ return profiles. This process enables repackaging the risk of the asset pool to create tranches of different risk levels. Since

structured securities like CDOs are rated by rating agencies like Standard and Poor's (S&P), Moodie's and Fitch, the tranches receive different ratings according to their risk exposure. Hence, tranches of superior ratings compared to the average collateral risk can be created (Coval et al., 2009). Non-agency CMO tranches may be structured according to default risk exposure, where senior tranches are most protected against defaults. CMO cash flows are distributed in a waterfall structure according to the seniority of the loans, thus the junior or subordinate tranches receive interest payments and principal payments only after the more senior tranches have been paid. This process is referred to as credit enhancement since senior tranches receive AAA ratings out of much lower rated pool of MBS due to the transferred default risk to the subordinate tranches, which receive ratings below the investment grade. The expected yield for CMO investors of the tranches is structured according to their seniority, thus subordinate CMO tranches are compensated by higher yields. Typical investors for the subordinate tranches are hedge funds and other specialized investors, who can assess and hedge the involved risks. In addition to the subordination technique, measures like overcollateralization are used for credit enhancement, where excess collateral is placed in the CMO in order to protect against losses due to defaults (Fabozzi, 2005). In order to further benefit from credit enhancement, the tranching process used in CDOs can be extended by creating a pool of junior or subordinate tranches of CDOs to create a so called CDO-squared, which repackages the pool of tranches, similar to the conventional CDO (Coval et al., 2009). Here the credit enhancement process can create AAA rated tranches out of a pool of unrated subordinate tranches due to the discussed credit enhancement technique that theoretically absorbs the risks.

During the financial crisis, the market for structured finance instruments grew significantly. Due to the soaring market for subprime mortgages, a large portion of the CMOs contained subprime and other non-conforming mortgages. The expected return of these structured products is very

sensitive to its parameters like default rates and default correlations. Since these parameters were estimated through complex historical models, adequate data for default rates of these loans were not available. The complexity and nature of structured finance instruments like CMOs amplifies the exposure to changing market conditions and in particular the senior tranches concentrate the systematic risks, since the idiosyncratic risk portion is transferred to the junior and subordinate tranches (Coval et al., 2009). This circumstance makes structured products like CMOs particularly prone for substantial losses during market crashes. Although yields of AAA rated CMO senior tranches exceed those of similarly rated corporate bonds, which indicates partial compensation for increased systematic risk exposure of CMOs, the study of Coval et al. (2009) highlights, that this risk premium is insufficient for the expected losses during recessions. Moreover, the yields of the senior tranches are still low as a supposedly safe investment grade asset, causing the junior tranches to be overcompensated in excessive yields. Hence, many investors were incentivized to invest in the highly risky junior tranches, further fueling the subprime mortgage market, since the additional supply of subprime mortgage financing reduced the borrowing costs. Finally, a crucial aspect of CDOs is the correlation of the underlying assets. The less correlation between the underlying assets exists, the more effective is the credit enhancement and the potentially safer the senior tranche can be (Coval et al., 2009). The CDO- squared are significantly more sensitive to parameter changes than normal CDOs since increased default rates or default correlations impact the CDO-squared tranches heavily. In order to hedge their credit risk exposure, CDO/CMO investors can acquire credit default swaps (CDS) as insurance against the default of the purchased tranches. However, the credit risk of the insurer has to be considered.

2.5. The Financial Crisis and the Role of Mortgage Backed Securities

The financial crisis is considered as the worst crisis since the Great Depression and formed relatively quickly. Securitized mortgage instruments played a substantial role during the financial

crisis. In order to fully understand the risk nature of these assets as well as the historical behavior during the crisis a detailed overview of the financial crisis is provided in this section. First, the events leading to the financial crisis are described, followed by a sub-section concerned with the key stakeholders of the crisis.

2.5.1. Circumstances Leading to the Financial Crisis

During the years before the crisis, the economy was healthy and expanded continuously since the high-tech bubble in the early 2000s. After the high-tech bubble, the US economy was shaped by a low interest rate environment due to extensive foreign investment and a lax interest rate policy by the Federal Reserve the boost the economy (Brunnermeier, 2009). Also, financial institutions changed their business model towards the securitization process to subsequently distribute instead of lend and hold the loans. Instruments like CDOs became very popular and allowed banks to transfer the credit risk of the originated assets to other parties. This process reduced the incentive for banks to assess the risk and loan performance of the securitized mortgage pools (Brunnermeier, 2009). These characteristics of the economy lead to a soaring housing market because the low interest rates and confidence in the economy increased the hunt for yields of investors and the attractiveness of alternative investments as well as the accessibility of loans.

The increased number of MBS created by Fannie Mae and Freddie Mac were highly demanded, however the supply of low-risk conforming mortgages, which were originated during the years before the financial crisis, had limits. The majority of originated mortgages qualified as conforming mortgages, where borrowers had to present various indicators for income stability and long-term ability to pay back the mortgages. This characteristic lead to the low default risk of agency mortgages and rendered lenders more optimistic during the years before the financial crisis and

GSEs provided credit guarantees for these loans effectively eliminating the mortgage's default risk. The subprime market for mortgages already existed since the inception of the MBS market, however its size was very small in comparison to the total MBS market. The subprime non-agency-MBS market evolved as the credit scoring technologies improved and online investigations became possible. The new technologies enabled automated underwriting through automated online scoring of potential borrowers, which saved a significant amount of time and money per loan application. This sharp decrease in application processing costs increased the profitability of the mortgage originators. These processes generated a 40% increase in subprime mortgages resulting in $ 450 Billion of subprime loans in 2005 which accounted for 20% of new loans and 10% of total mortgage loans that year (Johnson & Neave, 2008). The qualitative assessment of loan applicants was essentially substituted for automated scoring programs, which selected conforming borrowers through fixed attributes. This lead to a large amount of approved subprime borrowers.

The growing market attracted new players, increasing the competition for mortgages and in order to maintain the profit levels, the requirements for conforming mortgages were relaxed by the loan originators. Since mortgages were insured against defaults by wall street banks, the incentive for adequately inspecting the loan applicants was reduced, since default risk was transferred to the insurer. Moreover, new forms of mortgages, like teaser loans, were created with initial low interest rates and subsequent adjustable interest rates linked market rates. These loans further attracted subprime borrowers and when interest rates increased, default rates soared (Johnson & Neave, 2008). These mortgages had significantly more default risk because the lenders needed to proof less credit worthiness, however with increasing risk for the MBS investors, risk monitoring activities were not altered. The riskier MBS portfolios were still insured against default risk and some insurers even reduced insurance fees for gaining market share, reducing the incentive for

investors to increase risk management activities. Besides, the MBS portfolios were tranched into tailored risk/return profiles depending on ratings and prepayment expectations, which corresponded to different risk exposure profiles of investors. The competitive yields of the MBS/CDO portfolios and tailored risk profiles were attractive investments and lead to a booming subprime MBS market in the years before the financial crisis. According to Johnson & Neave (2008), the warning signs of "growing competition for new loans, relaxation of quality screening, and under-emphasis of residual risks" were ignored by the market participants due to the strong returns and the supposedly inexistent default risk thanks to credit insurances.

Before the financial crisis 75% of mortgage loans were securitized by GSE like Fannie Mae and Freddie Mac. The securitized portfolios are sold to specialized investors and the default risk remains with insurer or in case of uninsured mortgages the default risk is transferred to the investor. Due to complex nature of securitized and tranched instruments like CDOs, the residual risk is often obscured. Investors of non-agency-MBS were institutional and specialized investors, which focused on the prepayment risk and interest rates of their MBS tranches. They ignored the default risk and relied on the ratings provided by the rating agencies. On the one side the high supply for MBS financing and on the other side, the high demand for mortgages, lead to the booming market between the early 2000s and 2007. The high supply for MBS financing originated from the lack of attractive investment alternatives for institutional investors during this period. The originators also contributed to the supply, since they could achieve high profits through the automated screening processes and focused on increasing the number of underwritings. Moreover, house prices rose by 11% per year between 2002 and 2007 leading to potentially high resale values of the properties, and reinforced expectations of continuous growth (Acharya & Richardson, 2009). For an increase in mortgage demand in line with the high supply, loan requirements were relaxed as described

above, and the subprime mortgage market soared leading to a high number of homeowners being attracted by low down payments and teaser loans with initial interest rates as low as 1% (Johnson & Neave, 2008). The low short-term investment horizon during the booming years of 2005-2007 appeared favorable in particular for the adjustable rate mortgages (ARM), but borrowers underestimated the potential for increasing interest rates leading to signigicantly higher mortgage costs. Teaser loans accounted for 80% of subprime mortgages and a slighly lower risk category for mortgages was created called Alt-A loans, which, similar to the subprime loans required downpayments of less than 10% and documentation of the borrowers was rarely inspected (Johnson & Neave, 2008). Before the crisis, around 40% of all mortgages were classified as subprime or Alt-A mortgages and since interest rates rose after 2004, the ARM debt payments became much higher. Moreover, at the beginning of the financial crisis, house prices started to decrease, leading to mortgages being of higher value than the underlying properties. Increased mortgages payments and decreased property values lead to increasing default rates and the defualt insurances became more costly in 2007, as insurers lost confidence in the booming market. These increased costs and risks could not be covered by many mortgage lenders, resulting in bancrupcies of 30 subprime lenders in early 2007 (Johnson & Neave, 2008). In line with a large number of defaults, the liquidity of the MBS market decreased substantially. Illiquidity in the mortgage market resulted in the inability to price securities and the credit spreads increased significantly (Johnson & Neave, 2008). This liquidity shock created a contagion, since investors attempted to sell their depreciated assets, but due to the illiquidity, there were no buyers in the market leading to a downward spiral that affected the overall market (Cohen-Cole & Sabry, 2014)

2.5.2. System of Perverse Incentives during the Financial Crisis

A system of perverse incentives that was developed in the private label and subprime mortgage market during the booming years before the financial crisis. Incentives for all stakeholders in the mortgage market were created to take advantage of the system without taking increased risk measures into consideration. The homeowners were incentivized to take mortgages they would not be able to pay back through multiple methods. First, the requirements for mortgages applicants were substantially reduced, which lead to the so-called liar loans, where borrowers could provide incorrect information in their mortgage application forms without facing consequences due to no subsequent data inspection. Secondly, the loan to value ratios increased to levels, where homeowners were not required to leave any or only below 10% of the property value as down payment for their mortgages. Finally, mortgage brokers attempted to aggressively attract subprime borrowers through teaser loans, which required very low initial interest rates, that would eventually increase to become adjustable rate mortgages with high spreads (Johnson & Neave, 2008). The combination of these mechanisms created the situation, that low-income borrowers took on mortgages without an equity commitment in their homes, which had the potential to become substantially more expensive through the ARM characteristic of the loans when interest rates rise. Thus, the probability as well as the incentive for homeowners to default on their mortgages was high when the interest rates rose.

Similar to the homeowners, brokers had strong incentives for offering as many mortgages as possible due to the fees earned through origination. Lenders focused on generating fees, rather than assessing the default risk of the loans originated. The resulting competition in the booming market lead to a continuous relaxation of credit requirements in order to maintain profit levels. Since subprime borrowers were not allowed to obtain conforming agency mortgages due to credit

restrictions, private label MBS were created with credit guarantees from Wall Street banks. These guarantees were, in contrast to the agency MBS, not backed by the US government and contained credit risk of the insuring bank. The default risk of the borrowers lost importance, since the loans were sold to investors in pools and insurers provided cheap insurances on the loans. Meanwhile ratings of these products remained on high levels. The complexity of the mortgage portfolios increased diversification effects, but "the opaqueness of the asset portfolios underlying the pool securities required extra diligence on the part of rating agencies, which apparently was not exercised in many cases" (Johnson & Neave, 2008). When the mortgage market became riskier through subprime mortgages and more complex securitization, lenders missed the opportunity to increase risk measures by increasing loan requirements and inspecting borrowers as well as monitoring existing mortgages (Johnson & Neave, 2008).

Financial institutions played a key role during the financial crisis with regards to structured products, because these institutions differed from their original role as a financial intermediary securitizing or packaging mortgages and other collateralized debt to CMOs and CDOs and subsequently selling the tranches to investors. Instead many commercial banks from the Wall Street became investors themselves and held large amounts of senior CMO and CDO tranches as these required low levels of capital requirements and provided superior returns compared to other AAA rated instruments like corporate bonds and AAA rated Credit Default Swaps (Acharya & Richardson, 2009). The pooling of a large number of mortgages diversifies away the specific risk of individual mortgages due to their low mutual correlations. The only risk remaining is the systematic risk of the mortgage pool, correlated to the overall economy. In particular the senior CMO tranches with subprime mortgages as collaterals were highly sensitive to systematic market downturns since these tranches only default, when the majority of underlying mortgages defaults

and the subordinate tranches have already defaulted. This situation would go in line with a substantial crash of the market and banks betted against this scenario, but for risk management purposes, many institutions hedged against a market collapse through credit default swaps provided by large insurers like American Insurance Group (A.I.G). In 2007, the gross notional amount outstanding of CDS ranged between USD 45 and 62 Trillion (Brunnermeier, 2009). However, when the market collapsed, the insurers were not able to deliver the promised insurance payments since the large amount of credit events occurred in a short period of time and insurers like A.I.G. had to file for bankruptcy, leading to losses of "158 to 473 billion on their holdings of AAA-tranches of mortgage- backed securities" for the financial sector (Acharya & Richardson, 2009). "The failure of the likes of Fannie Mae, Freddie Mac, and Lehman Brothers, which invested in the securities created out of these mortgages, led to severe counterparty risk concerns that paralyzed capital markets and thus caused the worldwide recession" (Acharya & Richardson, 2009).

Another stakeholder of the mortgage system are the regulators, which failed to put in place regulations that prevented the described spiral into more and more risky financial products and subprime mortgages. The Basel 1 and Basel 2 regulations, which were in place during the financial crisis, tied bank's capital to assets to AAA-ratings, not differentiating between ratings for bonds or structured instruments like CDOs (Johnson & Neave, 2008). This further increased the incentive for these institutions to invest in AAA- rated tranches of CDOs and CMOs with attractive yields. Additionally, financial institutions deferred from ususal practices of transferring the credit risk of their investments to investors during the securitization process. Instead, large financial instituitons like investment banks, insurance companies and hedge funds were heavily invested in the risky junior and subordinate tranches of CMOs and CDOs (Acharya & Richardson, 2009). When these assets became illiquid during the financial crisis these firms had substantial amounts of junior

tranches and subprime pools on their balance sheets as investors stopped investment into these tranches (Coval et al., 2009). Market participants admitted after the crisis, that key stakeholders were aware of the risks they were taking and that they decided to ignore them to gain short term profits. A leaked email from a manager at a rating agency in December 2006 is representative of this behavior, describing, that their structured finance rating behavior creates an "even bigger monster—the CDO market. Let's hope we are all wealthy and retired by the time this house of cards falters" (SEC, 2008).The rating framework did not take into account the complexity and the substantial systematic risk nature of the securitized private label mortgages. For improving the transparency of structured products, it is crucial to recognize that CDOs unlike "traditional corporate bonds, whose fortunes are primarily driven by firm-specific considerations, the performance of securities created by tranching large asset pools is strongly affected by the performance of the economy as a whole"(Coval et al., 2009). This circumstance point to the final stakeholder in this crisis, the rating agencies.

The major rating agencies Moody's, S&P and Fitch were in charge of providing credit ratings for fixed income products like mortgage backed securities. These institutions have access to privileged information and thus have a large responsibility for providing accurate and objective ratings. However, criticism arose due to conflicts of interests during the financial crisis, since the issuers pay the fees for the credit ratings instead of the investors (He, Qian, & Strahan, 2011)**.** On the one side, **t**his structure may have led to biased ratings, since the rating agencies attempted to secure future mandates, but on the other side the agencies were concerned of potential losses of reputations due to inaccurate ratings. During the years before the financial crisis, the top five issuers of private MBS deals accounted for 38 to 47% of the total private MBS deals and thus had substantial bargaining power. Since the demand for AAA rated assets is the highest an incentive for rating

agencies was created to provide the top ratings (He et al., 2011). The demand for AAA tranches was particularly high from financial institutions since regulators required less capital reserves for top rated assets. Securitized mortgage instruments fitted perfectly into this framework as these institutions could benefit from the attractive yields and the low required capital reserves of these assets. This characteristic is particularly evident when comparing the portion of AAA rated tranches to the portion of AAA rated corporate bonds, where only approximately 1% are top rated versus approximately 94% of privately issued AAA MBS tranches (He et al., 2011). Finally, rating agencies received higher fees for assessing structured instruments like CMOs, than for corporate bonds due to the complexity of these products, leading to further inventive for to provide top ratings on these complex instruments in order to secure future rating mandates for the agencies (Brunnermeier, 2009).

The rating process for structured products like MBS differs from the traditional corporate bonds because the issuing firm is not in the focus of the assessment, instead are the "large number of credit-sensitive assets" which are pooled and tranched as the underlying of the security. The pool of collaterals is separated into prioritized claims, that "absorb losses from the underling portfolio following seniority; hence, tranche-level ratings depend both on the risks and diversification from the collateral pool as well as on the structuring of the cash flows" (He et al., 2011). According to Coval, Jurek, & Stafford (2009), the rating models of the rating agencies used for assessing structured financial product like CDOs were not error proof and small and minor imprecisions in the assessment parameter would have resulted in significantly different ratings. Another issue concerning the credit agencies is, that the rating does not provide "information regarding whether the security is particularly likely to default at the same time that there is a large decline in the stock market or that the economy is in a recession" (Coval et al., 2009). Since, in particular structured

instruments, like CDOs and CMOs, are highly exposed to systematic risk, CMO ratings can be considered as obscuring the substantial systematic default risk. Consequently, AAA- rated mortgage instruments defaulted and lost significant value during the financial crisis, which casted "doubt on the diligence of the rating agencies in inspecting and monitoring the securities, as do the incomes the agencies earned by making the ratings" (Johnson & Neave, 2008). Another issue reagrding the rating approaches of complex instruments like CMOs was treating the ratings of products like CMOs as equivalent to the ratings of conventional fixed income products like corporate bonds leading to an apparent comparabilitiy of the the two substantially different types of securities. This mechanic created the incentive for investors to not conduct due diligences on CDO and CMO investments, but rather to trust the ratings and to compare these complex instruments to similarly rated bonds.

In conclusion, securitized mortgage instruments played a key role during the financial crisis and the booming economy and housing market as well as the hunt for short term yields created a framework of perverse incentives for all stakeholders to make short term profits at the expense of risk assessement. Under these circumstances, complex instruments, like CMOs, were engineered and supported by rating agencies as regulators, to profit from the growing subprime mortgage market. The substantial systematic risk exposure eventually lead to the unfolding of the financial crisis when a larhe number of subprime mortgages defaulted and liquidtity decreased substantially leading to a downward spiral in the wider financial markets.

3. Data Analysis

The data analysis section is organized as follows. First, a market analysis is conducted to provide an overview about the discussed markets. In the methodology, the portfolio and mean-variance theory and mathematics are explained. Subsequently, the model used for the mean-variance computations is described as well as the data used for the optimizations. Finally, the portfolio optimizations are conducted in the last sub-section of this chapter.

3.1. Market Analysis

This section will provide an overview about the mortgage market as well as a set of financial assets by analyzing market data about the securitized mortgage market, including MBS issuance, the performance of the subprime market during the financial crisis, followed by an analysis of the CMO market as well the CMBS market. Afterwards, the market for real estate is analyzed, starting off with the performance of the REIT market, followed by a comparison between direct and indirect real estate and concluding with an analysis of a hypothetical mixed portfolio.

3.1.1. Securitized Mortgage Market

The market for agency and non-agency MBS experienced a strong growth during the years before the financial crisis as displayed in chart 3. Both segments grew from around USD 615 billion in 2000 to more than USD 2.7 trillion in 2003, at this point, the saturation of the demand for conforming mortgages reached high levels, leading to a decline in agency-MBS and a substantial growth in the market for non-agency MBS. The market share of non-agency MBS was stable between 2000 and 2003 at around 22%, however in 2004 the market share jumped to 46% and continued its growth in issuances of 44% which was in line with 2002 and 2003. The agency MBS issuances fell by more than 50% in 2004 compared to the previous year and remained at stable

levels between 2004 and 2006 at around USD 1 trillion. The non-agency issuance volume continued its growth until 2006, reaching a 56% market share with volume of more than USD 1.1 trillion. At the peak of the financial crisis in 2008, the market for non-agency mortgages nearly disappeared with issuances declining by 92% compared to 2007 leading to a market share of 5% in 2008 and 4% in 2009 while agency MBS issuances experienced a growth of 48% in 2009 after a decline of 7% in 2008. The strong increase observable in 2009, was due to the intervention of the US Federal Reserve in January 2009, which decided to start purchasing large amounts of agency MBS to be held on its balance sheet as a measure of quantitative easing. Between 2009 and 2013, issuance levels were relatively stable, ranging between USD 1.7 trillion and USD 2.1 trillion and non-agency MBS issuances had a share between 3% and 6%. The Federal Reserve acquired total holdings of approximately USD 1.8 trillion of agency MBS until April 2014 and continued to roll over the securities to keep a constant balance at this volume. This indicates, that the Federal reserve is a dominant player in the agency MBS market (Federal Reserve Bank of St. Louis, 2017). The federal reserve has decided in 2017 to shrink its balance sheet, to reduce quantitative easing measures, which may include getting rid of the MBS holdings (Fleming & Wigglesworth, 2017).

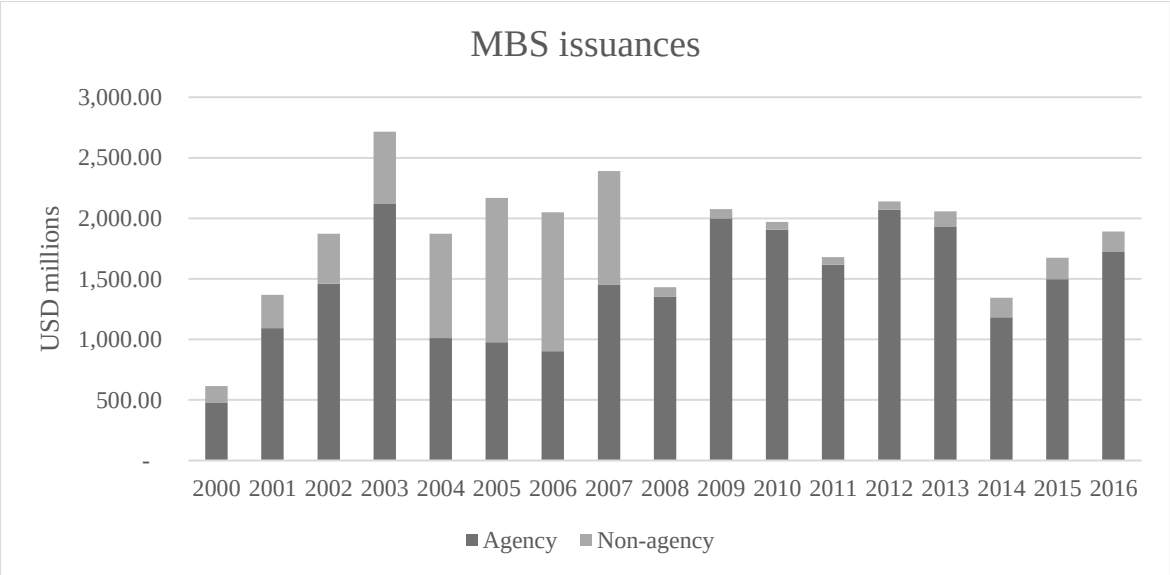

Chart 3: MBS issuance volume, 2000-2006 adopted from Cohen-Cole & Sabry (2014) with data from Inside Mortgage Finance and 2007-2016 adopted from SIFMA Securitization Year in Review (2017)

3.1.2. Subprime Market Performance during the Financial Crisis

As described in section 3.1.1, the subprime mortgage market grew exponentially during the years leading to the financial crisis. Due to securitization and financial engineering, complex instruments were developed to serve the demand for high yielding subprime mortgage investments. These instruments are exposed to significant systematic risks and during the crisis, not only the subordinate tranches of subprime instruments, but also the AAA- rated tranches suffered substantially and liquidity for these instruments disappeared. Commonly used indices for analyzing the subprime market are the ABX indices by Markit. These indices are relatively complex, but offer an assessment of the "investors' perception of the subprime market and their expectations about the expected defaults of the underlying mortgage collateral" (Cohen-Cole & Sabry, 2014). In fact, the Home equity asset-backed securities index (ABX.HE) gauges the actual and expected default risk, possible loss of liquidity as well as substantial changes in the macroeconomic environment affecting the respective subprime market segment. The ABX.HE index tracks the performance of 20 equally weighted sub-indices, which are each "composed of CDSs on tranches of 20 of the largest subprime ABS for the relevant time period" (Cohen-Cole & Sabry, 2014). The 20 sub-indices offer an analysis of segments of the subprime market, hence the different subprime tranches ranging from AAA to BBB- can be assessed. There is substantial evidence for an over-estimation of the ABX of the effects of the financial crisis on the subprime market due to a limited set of CDS in the sub-indices and a significant impact of risk perception as well as illiquidity concerns on the index price (Cohen-Cole & Sabry, 2014). Nevertheless, chart 4 displays the ABX.HE index consisting of several tranches of ABX credit default swaps issued in July 2006 at par (100% of the

asset value). It can be observed, that all tranches remain at par until November 2006, where the most subordinate tranches (BBB-) start to decline, followed by the other tranches in order of seniority. Interestingly, the AAA tranches only started to decline in July 2007, more than half a year after the BBB- tranches did. This indicates the absorption effect created through credit enhancement as discussed in section 2.4.3. At the peak of the crisis the BBB-, BBB and A rated tranches were only worth a few cents on the dollar, demonstrating the extensive liquidity shock in the subprime mortgage market. Even the senior AA rated tranches were only worth around 10 cents on the dollar and the top-rated tranches were worth less than 50% of their par value.

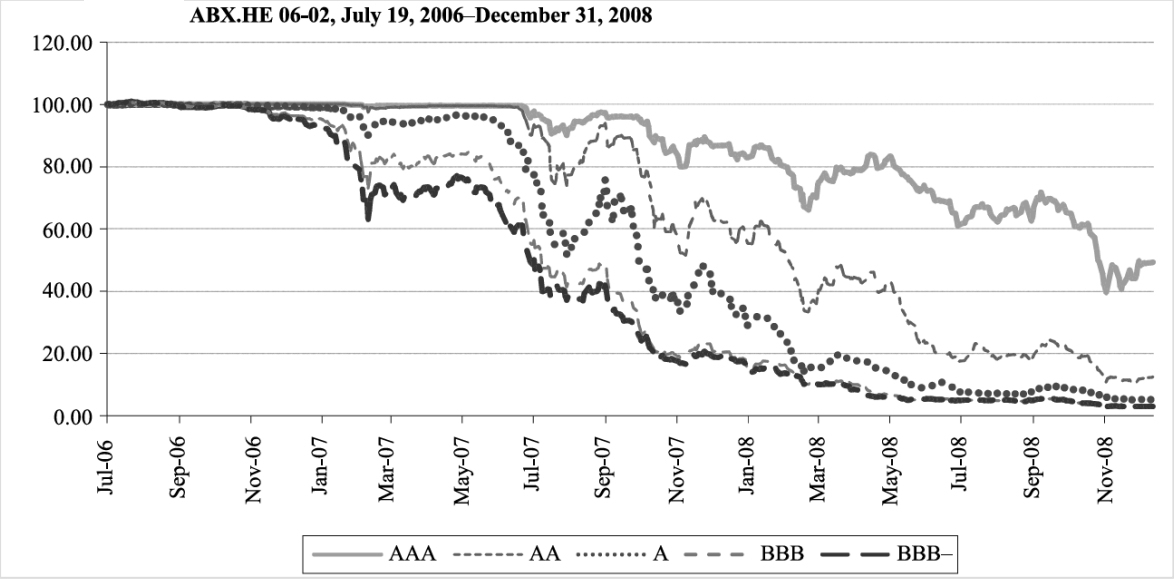

Chart 4: ABX.HE 06-02, from Cohen-Cole & Sabry (2014)

3.1.1. Collateralized Mortgage Obligations Market Analysis

The market for collateralized mortgage obligations behaved similarly to the MBS market, but with a sharper decrease in liquidity during the financial crisis. In chart 5, the US issuance volume of CMOs between 2001 and 2016, segmented by collateral type, can be observed. There are four collateral types analyzed, the three agency- guaranteed mortgage series of Freddie Mae (FHLMC),

Fannie Mae (FNMA) and Ginnie Mae (GNMA) as well as Whole loans (Whole), which are CMOs that are not backed by agency guaranteed mortgages. In the beginning of the observed period, the issuance volumes increased substantially in all observed segments. In particular, the Whole loan segment increased strongly. CMOs backed by non-agency loans are generally riskier due to underlying mortgages that do not conform with the agency standards and the lack of GSE guarantees. Amounting to only 31% of the analyzed CMO issuances in 2001, this segment had a share of 71% in 2007, demonstrating the growth of this segment. This observation can be explained by the ceasing supply for conforming mortgages and the industry's growing focus on private label mortgages during the years leading to the crisis. After the crash, total CMO issuance volumes decreased from over USD 1 trillion in 2005 to USD 191 billion in 2008. As expected, the Whole loan segment had the strongest decrease, from USD 700 billion in 2005 to only USD 50 billion in 2008. CMOs backed by agency mortgage faced only small issuance decreases and they picked up during the subsequent years while non-agency loan backed CMOs remained a minor segment, similar to the non-agency- MBS market, with only 8 to 10% of total issuance volume between 2011 and 2014. In contrast to the agency-MBS market, the agency-CMO market could not reach pre-crisis levels until now.

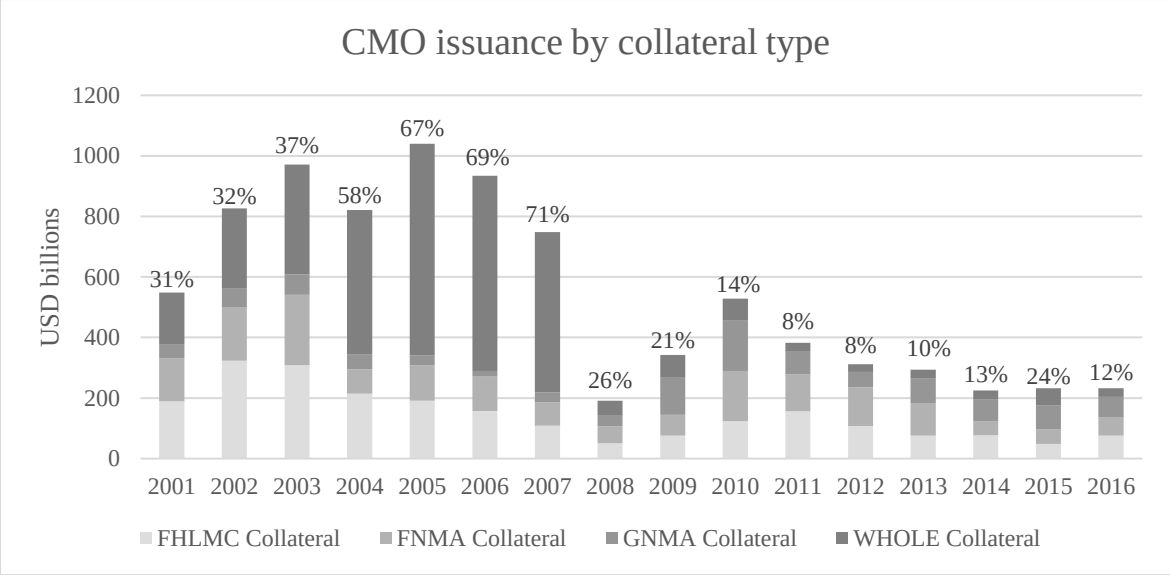

Chart 5:CMO issuance by collateral type, percentage values represent share of Whole segment Data retrieved from Bloomberg

3.1.2. Commercial Mortgage Backed Securities Market Analysis

When analyzing the commercial mortgage backed securities market, a similar behavior compared to the RMBS market can be observed. In chart 6, the national volumes in USD billions and corresponding capitalization rates between 1995 and 2017 of the major CMBS property types retail, multifamily, hospitality and office as well as the yield of the US 10-year government bond yield (GT10 Yield) can be observed. The capitalization rates or cap rates refer to the inverse of the price/ earnings multiple used in assessing commercial properties. It is calculated as the ratio of property operating earnings and the property value (Geltner et al., 2006). A linear relationship can be observed between the office, multifamily and retail cap rates to the treasury yield. In fact, the respective correlation coefficients of the cap rates to the treasury yield are strong and amount to 79.21% for retail, 84.88% for multifamily and 77.81% for office. There is evidence, that treasuries in addition to credit availability and supply/demand as well as inflation predict cap rates (Mouchakkaa, 2015). During the first years observed, the CMBS market was very limited and

started to grow during the early 2000s. A similar behavior was observed in the RMBS market as described above. Strong growth is visible from 2003 until the peak of the financial crisis in Q1 2007 with a total CMBS volume of USD 54 trillion. The retail and office CMBS segments were the largest during this period and a particularly strong increase in office CMBS volumes can be observed during 2006. In the aftermath of the financial crisis the CMBS market volume dropped by 99.8% between Q1 2007 and Q3 2008, indicating a substantial liquidity squeeze in the CMBS market, similar to the subprime RMBS market. All analyzed cap rates decreased until the financial crisis in line with the decreasing yield of the risk-free rate (GT10). The retail and multifamily cap rates show a similar behavior between 1995 and 2007, decreasing from nearly 10% to approximately 6% with a correlation coefficient of 89.5%. The hospitality cap rates show a very volatile behavior which may be explained by a lower market volume leading to more noise in the cap rate values. After the crisis, market volumes remained low until Q1 2012 were volumes in all four segments increased substantially to total volumes of more than USD 30 trillion. Volumes continued to grow until now, surpassing the peak volumes of the financial crisis indicating a recovery in the CMBS market. Cap rates continued to fall until reaching a plateau around 5.5% for retail, office and multifamily cap rates, while hospitality rates remained very volatile. In recent years, the volume of multifamily CMBS grew significantly becoming the largest CMBS segment.

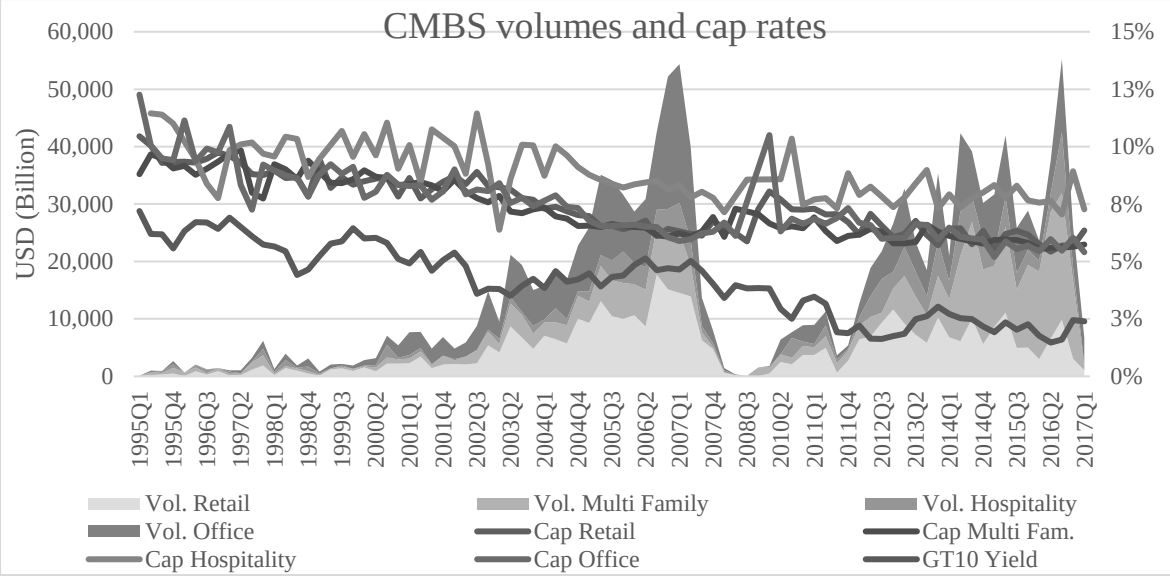

Chart 6: CMBS market, Data retrieved from Bloomberg

3.1.3. Real Estate Market Analysis

In this section, the real estate market will be analyzed by first assessing the REIT market by the performance of the underlying property types. Subsequently, the market capitalization of the four main REIT property types is discussed. The third part of this section compares the performance of direct real estate to indirect real estate investments and finally, the performance of the mortgage REITs to the securitized mortgage market is analyzed.

3.1.4. Real Estate Investment Trust Market Performance

In chart 7, the performance of the REIT market by property type is presented over the period between 2005 and 2017. The National Association of Real Estate Investment Trusts (NAREIT) provides a wide range of REIT indices. The quarterly cumulative return of the NAREIT Total Return indices of the different property segments indicate a homogenous behavior during the observed period. After an initial stable period, the overall REIT total return index dropped by more

than 58% between March 2008 and March 2009. The strongest decline during this period can be observed with the industrial REITs (-80.1%), followed by REITs focusing on retail properties (-68.1%). Least affected by the financial crisis were specialty REITs with a decline of 28.3%. During the years after the crisis, the REIT indices recovered to a large extend, leading to current levels above 2008. This reversal is in line with rallying property prices as well equity levels after the financial crisis. Industrial REITs remained volatile and underperformed the other REIT segments until 2016. The highest annualized return over the analyzed period is achieved by residential REITs (11.72%) and apartment REITs (11.41%), which also have similar standard deviations of around 24%. This similarity is expected due to similar type of properties. As expected, the industrial REITs have the highest standard deviation of 32.77%. A high correlation between the NAREIT segments can be observed, with correlation coefficients greater than 79.25% (between industrial and apartment REITs). Hence, the NAREIT Total Return sub-indices are highly correlated and the apartment and residential REITs appear most attractive from a risk/ return standpoint.

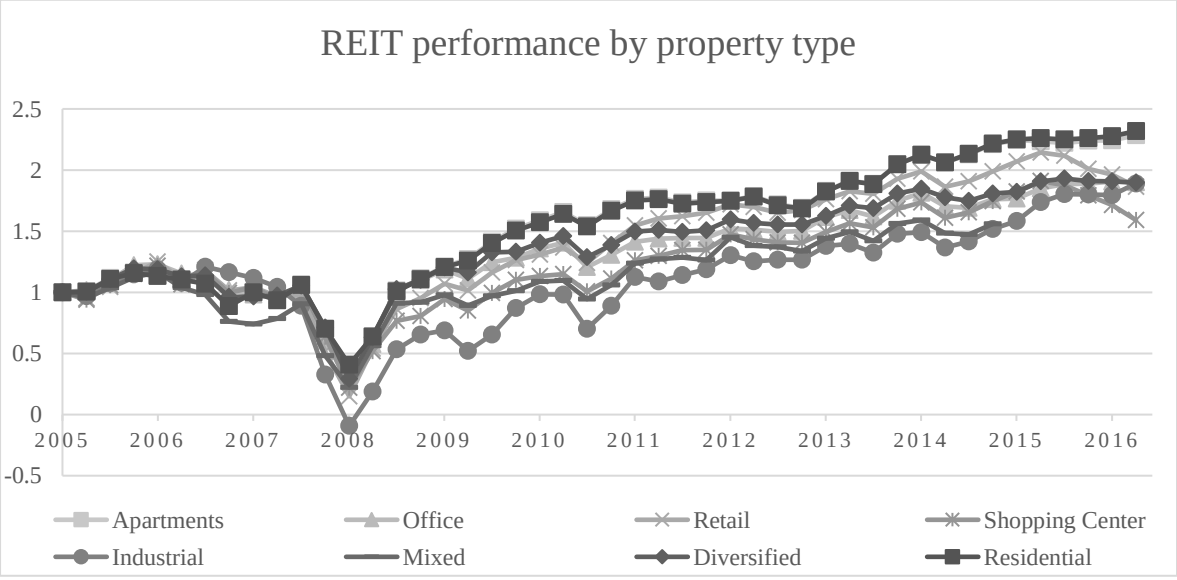

Chart 7: REIT performance by property type, Data retrieved from Bloomberg

3.1.5. Comparison of Direct and Indirect Property Markets

When comparing the performance of the major indices for direct and the indirect property markets during the last 20 years, several key differences can be observed. In chart 8, the cumulative quarterly returns of the NAREIT Total Return Index (NAREIT TR) and the National Council of Real Estate Investment Fiduciaries Transaction Based Index (NCREIF TBI) are plotted. The NCREIF TBI index is based on transactions and is less exposed to valuation smoothing errors as other direct property indices. Hence, this index is more volatile than the NCREIF Total Return Index. During the late 1990s, the fall of the REIT market can be overserved, which was due to a loss in confidence in the REIT sector as described in section 2.3.3. After the dot com crash, REIT returns gained until mid-2007 when the financial crisis started to affect the REIT market. Direct property returns remained relatively stable in the long term and continuously rose until the property prices declined in course of the financial crisis until September 2009. The REIT Index suffered the strongest losses between October 2008 and March 2009 of more than 58%, while the NCREIF TR Index only lost approximately 28% during the same period. This indicates a decoupling of the REIT performance from the underlying direct property performance. A reason for this behavior is the higher correlation to wider equity markets of the REIT market, causing more negative effects from the crisis. Another reason for the observed underperformance of REITs compared to direct real estate investments is the characteristically high leverage ratios of REITs, which lead to increased financing costs during the financial crisis, when cost of debt soared. Sun, Titman and Twite (2015) analyze the effect of leverage on REIT performance and find evidence for a negative impact of high leverage ratios of the firms as well as a negative impact of debt maturing during the crisis. In order to pay their debt obligations, REITs had to sell properties during the recession at a discount leading to shrinking NAVs and worse performance. Hence, the high debt exposure has amplified the effect of the crisis on REITs.

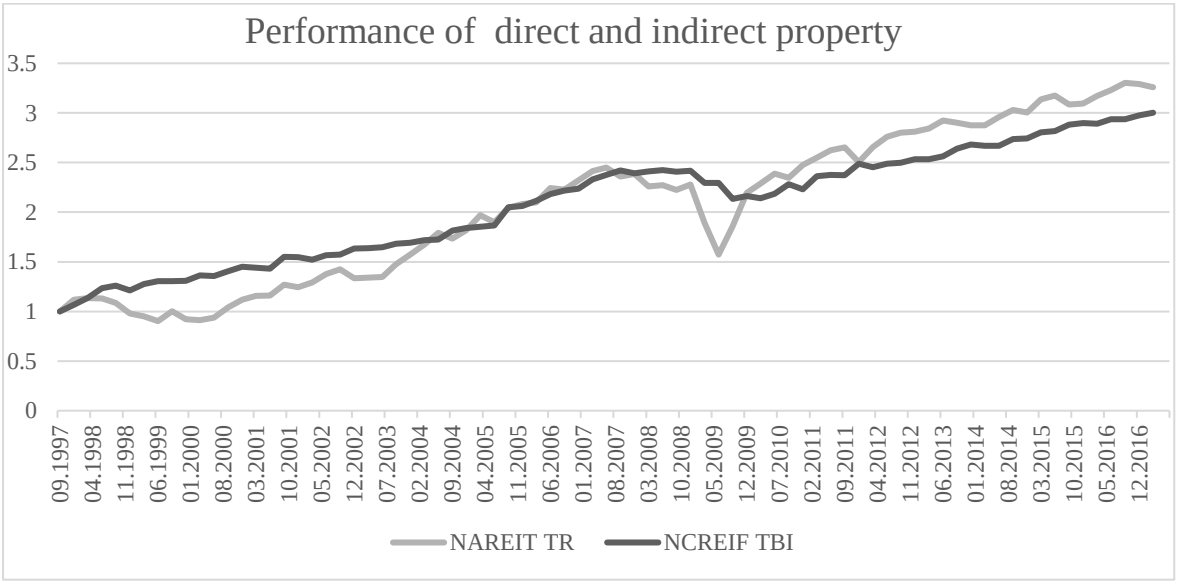

Chart 8: NAREIT/ NCREIF performance, Data retrieved from Bloomberg

3.1.6. Performance of a Mixed Portfolio

A main objective for investors is to diversify their holdings through multiple asset classes. As described in section 2.1, the main asset classes are equities, cash and fixed income as financial assets as well as direct real estate as a real asset. Chart 9 plots the cumulative quarterly returns between 1997 and 2017 of the major indices representing the abovementioned asset classes. Equities are represented by the S&P 500 Total Return Index, which includes the 500 largest US public companies. Fixed Income is represented by the S&P 500 Investment Grade Corporate Bond Total Return Index and the 10-year US Treasury Total Return Index. Securitized mortgage instruments as part of the fixed income asset class are represented by the agency MBS Total Return Index as well as the CMBS Index. Finally, real estate performance is tracked by the NCREIF Total Return and NAREIT Total Return indices. An immediate differentiation between the asset classes, equities, fixed income and real estate is possible when observing the chart. The fixed income

securities have the least volatile performance and seem to have not been affected much by the financial crisis. The two real estate indices on the other hand demonstrate a volatile performance, the NAREIT index being significantly more volatile. The REIT market, however suffered substantially more from the financial crisis than the private property market. The S&P 500 Index, was also more volatile than the fixed income indices and had substantial losses during the crisis. A second observation is, that the cumulative returns of the NAREIT Index were the highest reaching approximately 225% until the end of 2016 followed by direct property with around 186% and stocks with 158%. This analysis indicates that securitized mortgages behaved similarly to traditional fixed income securities during the last two decades and may be used as a substitute. Additionally, the impressive, but volatile performance of the covered real estate indices indicate, that they would be a return enhancing addition to a mixed portfolio.

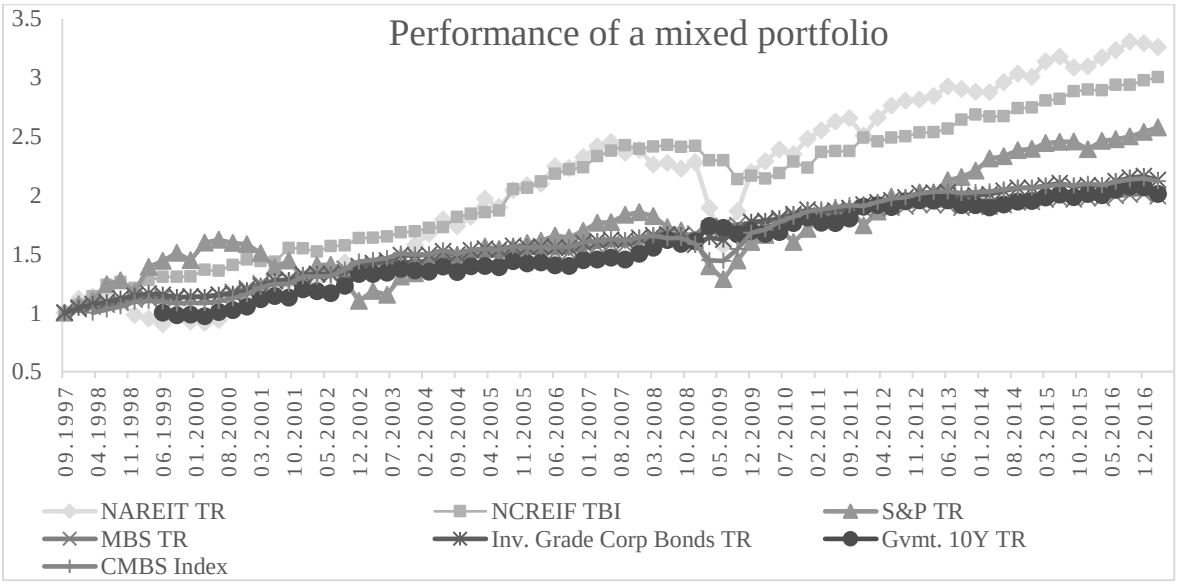

Chart 9: Performance of asset classes, Data retrieved from Bloomberg

3.2. Methodology

In this section, the methodology of the mean-variance optimization is described in order to provide the theoretical and mathematical background for the portfolio optimization conducted in section 3.4. First, the basics of the portfolio mathematics are briefly explained, including the diversification effect. Subsequently, the mean- variance framework is outlined followed by a description of the model used for conducting the optimizations.

3.2.1. Portfolio Mathematics

The expected return of a mixed- asset portfolio is calculated as the weighted average return of the individual assets:

$$E(R_P) = \sum_{i=1}^{m} w_i E(R_i)$$

Equation 1:Portfolio expected return

where E(R) represents the expected return based on historical data, i refers to one of the m individual assets included in the portfolio and w the individual weights. The standard deviation σ of an asset is calculated by the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[x_i - \mu]^2}$$

Equation 2: Standard deviation

where N denotes the number of values in the sample, x the individual values and μ the expected return. The volatility of a portfolio is not calculated as a weighted average, like the portfolio return, but as a weighted average of the variances of the underlying assets plus a covariance component:

$$\sigma^2{}_P = \sum_{i=0}^{m} w^2{}_i \ \sigma^2{}_i + 2 \sum_{i=1}^{m} \sum_{j=1}^{m} w_i w_j \ Cov_{ij}$$

Equation 3: Portfolio volatility

where Cov_{ij} refers to the covariance between assets i and j. The covariance can be calculated by multiplying the correlation coefficient between assets i and j with the product of their standard deviations. The correlation coefficient ranges between -1 (perfect negative correlation) and +1 (perfect positive correlation). Extreme correlations rarely exist in reality, since perfect negative or positive correlations would indicate either an exact co-movement between assets or a symmetrical opposite movement. The lower the correlation coefficient between the assets in the portfolio is from +1, the higher is the diversification effect, a portfolio with perfectly positive correlations would not achieve any diversification. In order to better understand the diversification effect, a hypothetical portfolio of two assets with changing correlations is modeled. Chart 10 plots the possible combinations of portfolios consisting of two assets, a hypothetical stock with an expected return of 6% and a standard deviation of 20% as well as a hypothetical bond with an expected return of 3% and a standard deviation of 10%. The combinations depend on the weights of the assets, ranging from 0% to 100% of one asset. The top right corner represents a portfolio only consisting of the stock and the bottom left corner a portfolio fully invested in the bond. Five different correlation coefficients (ρ) between the two assets are modelled in order to demonstrate the diversification effect. A correlation coefficient of 1 between the two assets leads to no diversification effects, indicated by the straight line. With decreasing correlation coefficients, the leftmost point of the plotted frontier decreases in standard deviation, reaching its maximum diversification potential with a correlation coefficient of -1. Thus, by combining assets, which are not perfectly correlated, more attractive risk/ return characteristics can be achieved, since portfolios with less risk at a similar expected return can be built than by only investing in one asset. The

diversification effect demonstrates the interest of investors to invest in assets, which are not highly correlated to achieve portfolios with higher returns and lower volatility.

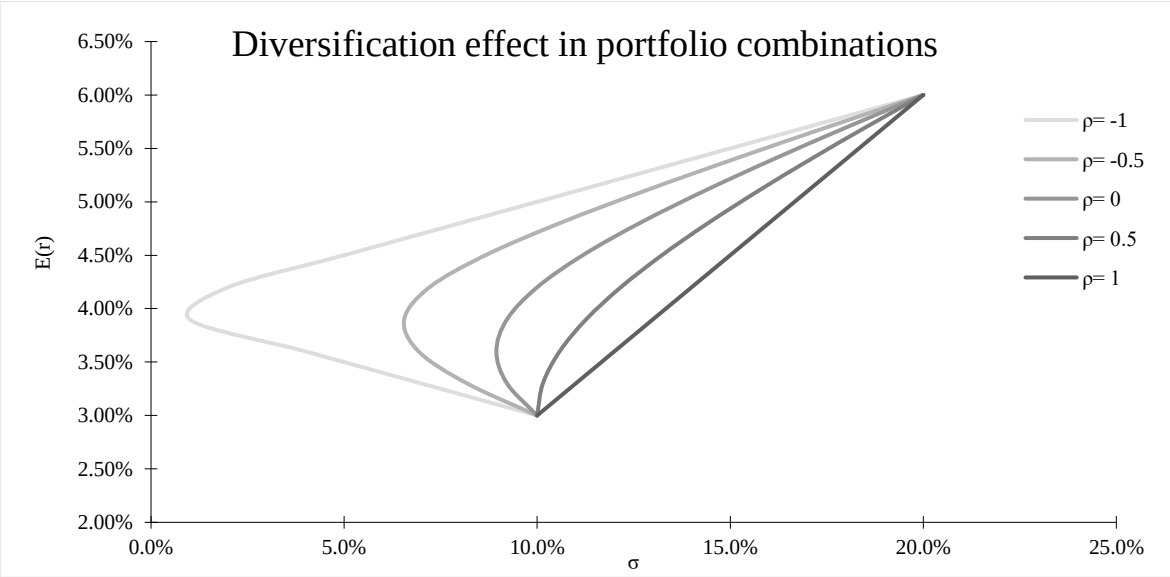

Chart 10: Portfolio combinations of two assets with varying correlations

3.2.2. The Concept of Mean-Variance Optimization

When optimizing portfolio allocations under the mean-variance framework, the concept of the capital allocation line (CAL) is essential for analyzing possible portfolio compositions. The CAL represents the opportunity set for an investor when investing in a risky and a risk-free asset. It plots the combinations of these two assets depending on their risk and return characteristics. Hence, the slope of the CAL is the reward- to- volatility ratio, also referred to as Sharpe Ratio (Bodie et al., 2014). The CAL is a straight line originating from the y-axis, at the risk-free rate of return (point Rf), until the point representing the risk/ return combination of the risky asset (point P). If an investor decides to have an equal investment in the risk- free and the risky asset, the chosen portfolio would be in the middle between the points Rf and P. The investor may also decide to borrow more funds at the risk-free rate to invest in the risky asset, these combinations lie on the

CAL to the right of point P. The investor can invest in a set of possible risky portfolios, depending on the combinations and weights of the underlying assets. When plotting the points of all possible combinations of portfolios, an area is created representing the portfolios. The border of this area is referred to as the efficient frontier, which marks all portfolios with the highest level of return at a given level of volatility. Portfolios, that lie inside the efficient frontier are not efficient and less attractive to an investor.

In the mean-variance framework, two efficient portfolios are commonly calculated which represent the most attractive portfolios consisting of a chosen set of assets. The first portfolio is the minimum-variance portfolio or global minimum- variance portfolio (GMV). This portfolio calculates the combination of risky assets that minimizes the variance of the portfolio regardless of expected return. In fact, the standard deviation of the GMV portfolio is always lower than the lowest standard deviation of any of the underlying assets due to the diversification effect. Hence, when plotting the efficient frontier, the GMV is leftmost point on the frontier (Campbell & Viceira, 2005). When analyzing a portfolio of two risky assets, the weight of the first asset (x) of the GMV portfolio can be calculated with the following formula:

$$W_x = \frac{\sigma^2{}_y - \sigma_{xy}}{\sigma^2{}_x + \sigma^2{}_y - 2 * \sigma_{xy}}$$

Equation 4: GMV portfolio weights

where σ denotes the standard deviation of the respective assets and σ_{xy} the covariance between assets x and y. The weight of the second asset is calculated by $W_y = 1 - W_x$. The second portfolio is the tangency portfolio, which calculates the portfolio with the highest Sharpe Ratio given the underlying assets. The tangency portfolio has the highest slope of the CAL and thus a tangency point between the CAL and the efficient frontier. Hence, the tangency portfolio provides the highest

level of excess return per unit of risk. In a two-asset environment, the formula for calculating the weight of the first risky asset (x) in the tangency portfolio is:

$$W_x = \frac{(\mu_x - R_f)\sigma^2{}_y - (\mu_y - R_f)\sigma_{xy}}{(\mu_x - R_f)\sigma^2{}_y + (\mu_y - R_f)\sigma^2{}_x - (\mu_x - R_f + \mu_y - R_f)\sigma_{xy}}$$

Equation 5: Tangency portfolio weights

Where μ denotes the expected return of the respective asset, R_f the risk-free rate, σ the respective standard deviation and σ_{xy} the covariance between assets x and y. The weight of the second asset is calculated by $W_y = 1 - W_x$. For calculating the tangency portfolio of a combination of more than two assets, spreadsheet calculations are required. In this study, optimizations are conducted using the solver add-in in excel, which allows for adjusting the optimization for certain constraints as discussed in the end of this section.

Since not all investors have the same level of risk aversion, an investor may decide to invest only part of his or her wealth into the previously calculated tangency portfolio and the remainder in the risk- free asset. Such a portfolio, consisting of the tangency portfolio and a risk- free asset, is called the optimal complete portfolio. This portfolio can be calculated by adding a risk aversion coefficient (λ) to the Sharpe Ratio formula to calculate the weight of the tangency portfolio in the optimal complete portfolio as shown in the following formula:

$$W_{\text{tangency}} = \frac{E_{R\ \text{tangency}} - R_f}{\lambda \sigma_{\text{tangency}}}$$

Equation 6:Optimal complete portfolio weights

The risk aversion coefficient ranges between 1 and 5 indicating a higher risk aversion, the higher the coefficient. Thus, a more risk averse investor would calculate a lower weight for tangency portfolio and invest the remainder in the risk-free asset. This optimal complete portfolio will still have the same Sharpe Ratio, since it lies on the CAL. Chart 11 plots the efficient frontier, the CAL

and the tangency portfolio of the hypothetical portfolio described above consisting of a stock and a bond with a correlation coefficient of 10%.

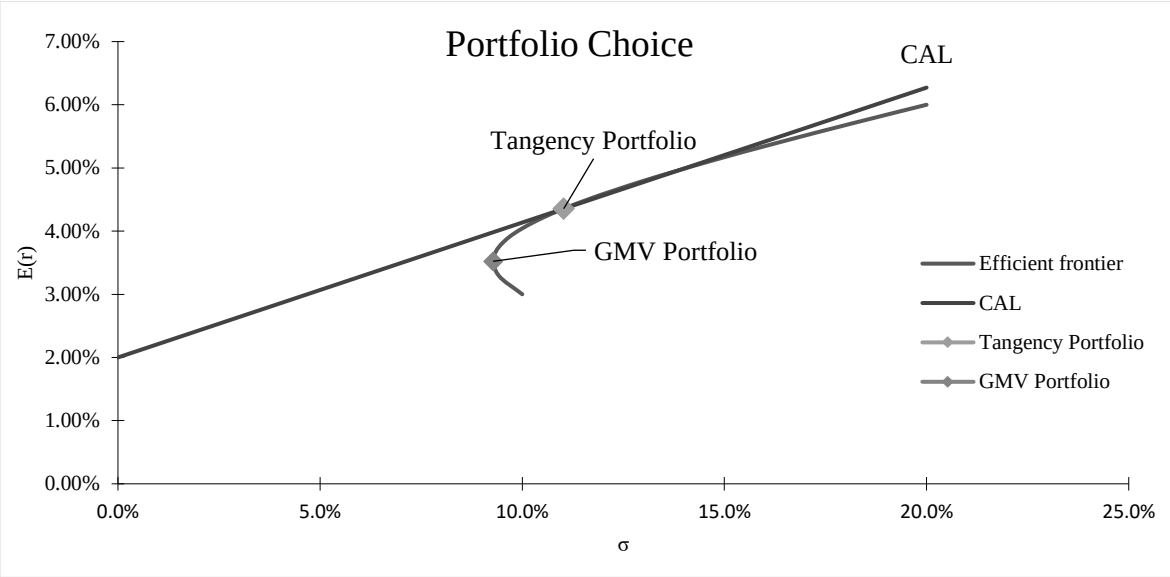

Chart 11: Efficient frontier, CAL, minimum-variance and tangency portfolio
Adopted from Bodie et. al. (2014)

3.2.3. The Portfolio Optimization Model

This study analyzes a portfolio of more than two assets, which requires the use of a spreadsheet to calculate the efficient frontier, the GMV portfolio as well as the tangency portfolio. An excel model was developed to calculate the weights of the tangency and the GMV portfolio and plotting the efficient frontier corresponding to a set of 20 target returns (Annex 1 and 2). The model includes a selected set of indices, for which minimum and maximum weight constraints can be set. According to Lee and Stevenson (2005), these weight constraints offer the benefit of restricting extreme allocations as well as promoting the "spirit of diversification" since more assets are included. Returns, cumulative returns as well as descriptive statistics are computed for the chosen set of indices. A detailed description and descriptive analysis of the assessed indices follows in the following sections. The next step is the calculation of a variance-covariance matrix, which

computes the variances among the selected indices, which is used for the matrix calculus conducted for calculating the portfolio standard deviations and returns. The solver subsequently optimizes the set of indices for the tangency, the GMV as well as the target returns of the efficient frontier. Criteria in addition to minimum and maximum weights are necessary for an accurate optimization process, namely a constraint, that the sum of weights sums to 100%, so that the portfolio is fully invested and that no negative weights are allowed. Restricting negative weights corresponds to the short selling restriction, which is common when performing mean- variance optimizations on realistic investment portfolios. The described restrictions and constraints on the asset allocations mitigates some of the shortcomings of the mean-variance optimizations since less extreme and more realistic portfolios are calculated that would be more in line with allocation requirements of investors. Finally, the computed weights of the tangency and the minimum variance portfolio are used to calculate descriptive statistics as well as cumulative returns of the respective portfolios. Furthermore, an equally weighted portfolio is generated to compare the performance of the computed efficient portfolios with a conventional portfolio choice. as well as a risk parity portfolio, which represent common asset allocation techniques used by professional investors. The risk parity portfolio is created by calculating the 20-period rolling standard deviations of the underlying indices. Subsequently, the respective rolling standard deviations of the individual assets in the period is divided by the sum of standard deviations in that period, which calculates the risk parity weight of that asset for the subsequent period. Finally, the returns of the risk parity portfolio are calculated by adding the product of the weights and returns of the analyzed assets in the respective periods. Hence, the risk parity portfolio distributes the portfolio volatility equally among the asset classes.

3.2.4. Data

For the portfolio optimization of this study, a hypothetical portfolio containing the asset classes equities, fixed income, mortgages and real estate is chosen. Such a portfolio represents a mixed portfolio with multiple asset classes that provide diversification benefits. The asset classes are represented by indices focused on the US market.

Quarterly data for the following ten indices were downloaded from the Bloomberg Terminal for the sample period between March 1999 and December 2016 and categorized into asset classes to be analyzed in the mean-variance framework. The majority of the selected indices are total return indices, which reinvest the cash flows received into the index and thus better represent investment into the respective asset classes. The first asset class are equities, for which the S&P 500 Total Return Index (SPXT Index) is chosen. The second asset class are bonds, which include the Bloomberg Barclays US Government 10 Year Term Index Total Return (BCEY4T Index), which represents an investment into US Treasury bills with a 10-year term. Secondly, the S&P 500 Investment Grade Corporate Bond Index Total Return (SP5IGBIT Index) is selected as an investment into low default risk corporate bonds. In addition to these conventional fixed income investments, indices for the securitized mortgage market are chosen. These include the Bloomberg Barclays US Mortgage Backed Securities Index (LUMSTRUU Index), which tracks the performance of agency MBS pass-through securities guaranteed by Ginnie Mae, Fannie Mae, and Freddie Mac. Next the Bank of America (BofA) Merrill Lynch US fixed Rate CMBS Index is included to represent investments in to the commercial mortgage backed securities. Furthermore, the following structured securities are included, the BofA Merrill Lynch US Agency CMO Index (CMOS Index), which consists of agency-MBS pass through securities; and the BofA Merrill Lynch 10+ Year US Agency CMO Z-Tranche Index (CM9Z Index), which is a sub-index of the

CMOS Index, representing exposure to the subordinate Z-tranche. The third asset class relates to real estate, as the public real estate investment vehicle, the FTSE NAREIT All Equity REITS Total Return Index (FNERTR Index) is selected, which includes all tax qualified REITs listed in the US. Additionally, the FTSE NAREIT Mortgage REIT Total Return Index (FNERTR Index) is included as exposure to the mortgage REIT market. Furthermore, the NCREIF Transaction Based Index (NPPINTBI Index) represents the private real estate market. This index tracks the income as well as appreciation at the property level, thus excluding leverage effects, of various commercial property types. The index differs from the basic NCREIF property index as it is based on transactions instead of appraisals. Hence, this index controls for issues like appraisal smoothing and is a superior index for assessing the return characteristics of direct real estate. NCREIF indices are a limiting factor for analyzing returns, as this index is only published quarterly, while daily data is available for the remaining indices. Hence samples sizes decrease significantly when including direct property investments. Finally, in order to calculate excess returns, the US Generic Government 3 Month Yield Index (USGG3M Index) is chosen as the risk-free rate.

3.3. Descriptive Analysis

Descriptive statistics mean to provide an overview about the return characteristics of the selected indices. In the table 1, descriptive statistics of the described data, over the sample period March 1999 to December 2016, can be observed. The highest annualized return over the period is achieved by the equity REIT index with 13.27%, followed by the mortgage REITs (9.05%) and the SPTX (6.40%), while the lowest return is unsurprisingly generated by the risk-free asset, the short-term treasury bill with 1.78%. This rate is used as the risk-free rate and applied for Sharpe Ratio calculations. The risk-free rate has also the lowest annualized volatility with 1.01%, followed by the NCREIF TBI index with 2.49%. The equity REIT index is the most volatile of the selected

indices with 21.26% standard deviation. The substantial difference in risk/return characteristics between the public and private real estate vehicles may hint at stronger similarities of the REITs to the wider stock market than to the private property market. Additionally, the difference may be caused by a difference in property types and the potentially riskier real estate investment strategy employed by the REIT managers versus the NCREIF index which focuses on stabilized properties in prime markets. The agency MBS index achieves the highest Sharpe Ratio with 1.13, followed by the CMO index with 1.10. This indicates a strong risk adjusted outperformance of the MBS and CMO markets during the observed period. Due to the essentially similar nature of the MBS and the CMO index explain the similar risk/ return characteristics. Another important measure for analyzing the returns of an index are skewness and kurtosis. Skewness measures the symmetry of the distribution of returns. The skewness is calculated by the average of the ratio of cubed deviations from the mean of the observed returns and the cubed standard deviations. Hence, this measure is also referred to as the third moment. If a distribution has a skewness of zero, the distribution is symmetrical around the mean, while a negative value indicates a distribution skewed to the left of the mean and the opposite is true of for a positive skewness. The skew of the indices to be optimized ranges between 0.59 (10- year treasuries) and -1.02 (equity REITs) except for the outlier Z-tranche CMO index with a slew of -2.99. The strong negative skew of the Z-tranche CMO index indicates, that the standard deviation underestimates the risk of the distribution significantly due to high negative extreme values. This is expected due to the high losses during the financial crisis which particularly affected the riskiest CMO tranches. Kurtosis is a measure indicating the probability for extreme values in the distribution. Hence, a distribution with fat tales has a higher occurrence of extreme values than a distribution with narrow tales and less values lie around the mean (Bodie et al., 2014). The kurtosis is calculated similar to the skewness, but to the fourth power, this measure is thus known as the fourth moment. A normal distribution has a kurtosis of 3, thus 3

is deducted in order to indicate the deviation from a normal distribution. Distributions with a kurtosis above the 3 of the normal distribution are considered as fat-tailed. The Z-Tranche index also has in this measure the highest value with 18.10, indicating extremely fat tales with a high probability of extreme values. In combination with the strong negative skewness, the analysis of the third and the fourth moment indicates a high probability of highly negative returns. Other indices with fat tales are the CMBS index (7.04), the equity REIT index (4.59) and the private real estate index with (3.70).

Descriptive Statistics							
Name	Index Description	Return	σi	Sharpe Ratio	Beta	Skew-ness	Kurtosis
SPXT	S&P 500 TR	6.40%	16.31%	0.283	1.005	(0.61)	0.30
FNERTR	Equity REIT	13.27%	21.26%	0.540	0.853	(1.02)	4.59
FNMRTR	Mortgage REIT	9.05%	23.42%	0.310	0.443	(0.43)	0.62
CM9Z	Z-tranche CMO	6.28%	14.10%	0.319	-0.283	(2.99)	18.10
LUMSTRUU	Agency MBS	4.85%	2.71%	1.131	-0.088	0.12	(0.07)
BCEY4T	Treasuries	5.69%	7.44%	0.525	-0.279	0.59	0.51
CMOS	CMO	5.09%	3.00%	1.101	-0.106	0.15	(0.23)
CMBS	CMBS	5.77%	6.88%	0.580	0.107	(0.34)	7.04
SP5IGBIT	Corp. Bonds	5.50%	5.14%	0.723	-0.007	(0.41)	2.15
NPPINTBI	Private Prop.	2.39%	2.49%	0.243	0.003	(0.28)	3.70
USGG3M	Risk-free	1.78%	1.01%	0.000	-0.010	0.81	(0.87)

Table 1:Descriptive Statistics of Indices

In addition to the descriptive statistics, the correlations between the indices are informative to make inferences about diversification effects. Table 2 displays the correlation matrix including p-values for significance levels between the 10 indices calculated in Stata. The p-values can be observed below the respective correlation coefficients. Correlation coefficients measure the level of co-movement between two series. The p-value represents the result of a hypothesis test, whether the respective correlation coefficient is statistically significant. For example, a significance level of

0.05 (5%) or less indicates that the respective coefficient is statistically significant at a confidence level of 95%.

The correlation matrix confirms the expectations gathered in the literature review, as the wider stock market is moderately correlated to the equity REITs with a coefficient of 0.65 and a weak correlation to mortgage REITs. This indicates a connection of the REIT indices to the wider stock market during the observed period. The remaining indices have weak and moderately negative linear relationships to the equity index despite CMBS (0.25) and corporate bonds and private real estate have statistically significant linear relationship to equities. Strong negative correlations to equities are found for treasuries (0.61) CMOs (-0.57) and MBS (-0.53). It can be concluded, that the securitized mortgage instruments have a negative relationship to equities and would offer strong diversification benefits when including the instruments into a portfolio with equities. The highest correlation coefficient when analyzing all coefficients can be observed between agency MBS and the agency CMO index with 0.94, which is close to a perfectly positive linear relationship. This can be expected by similar type of collateral of these instruments. Additionally, the agency MBS are strongly correlated to the fixed income indices treasuries (0.82) and corporate bonds (0.59) demonstrating statistically significant similarities of the securitized mortgage market to the fixed income market. The relatively high correlation among the three major fixed income instruments, the agency MBS, the treasury and the corporate bond index, indicates little diversification benefit among the fixed income assets. Notably, the coefficients of both MBS and CMO indices to the treasuries and corporate bond indices are higher than to the Z-tranche index. This may indicate, that the MBS and CMOs may behave more similar to treasuries and corporate bonds than to the risky tranches created through excessive securitization, although essentially being backed by a similar type of collateral. While the correlations of CMBS are statistically significant and

moderately strong to REITs, the correlation coefficients of the MBS and CMO indices to both, the REIT index and the direct property index, are close to zero and not statistically significant. This indicates possible diversification benefits of a portfolio including agency- mortgage instruments and commercial property investments. As expected, commercial mortgages in combination with commercial real estate is not beneficial from a diversification perspective. It is interesting to mention, that no correlation coefficient to the private real estate index is statistically significant at the 10% level. Hence, there is no significant evidence for a linear relationship of the indices to direct real estate. This indicates attractive diversification benefits of direct real estate, which is in line with the findings of Brounen et al. (2010).

Correlation matrix										
	SPXT	FNERTR	FNMRTR	CM9Z	MBS	BCEY4T	CMOS	CMBS	SP5IGBIT	NPPINTBI
SPXT	1.00									
FNERTR	0.65	1.00								
	0.00									
FNMRTR	0.31	0.49	1.00							
	0.01	0.00								
CM9Z	-0.32	-0.09	0.13	1.00						
	0.01	0.45	0.30							
MBS	-0.53	-0.09	0.13	0.57	1.00					
	0.00	0.46	0.28	0.00						
BCEY4T	-0.61	-0.23	0.01	0.61	0.82	1.00				
	0.00	0.06	0.90	0.00	0.00					
CMOS	-0.57	-0.11	0.10	0.59	0.94	0.85	1.00			
	0.00	0.36	0.40	0.00	0.00	0.00				
CMBS	0.25	0.60	0.35	0.30	0.27	0.10	0.29	1.00		
	0.04	0.00	0.00	0.01	0.02	0.38	0.01			
SP5IGBIT	-0.02	0.22	0.38	0.52	0.59	0.57	0.61	0.56	1.00	
	0.86	0.06	0.00	0.00	0.00	0.00	0.00	0.00		
NPPINTBI	-0.04	0.02	-0.17	-0.01	-0.09	0.07	0.00	-0.10	-0.02	1.00
	0.77	0.88	0.17	0.92	0.45	0.56	0.99	0.41	0.88	

Table 2: Correlation matrix with significance levels below coefficients

3.4. Mean- Variance Optimization

In the following section, the previously described indices are analyzed under the mean-variance framework. First, all ten indices are analyzed to discover the most attractive indices to be included in a diversified portfolio. Subsequently, several scenarios are created using the asset classes equities, bonds, mortgages as well as real estate and their performance is analyzed in detail. Transaction costs are to be ignored for the purpose of this study, but would occur in reality, in particular due to frequent portfolio rebalancing.

3.4.1. Portfolio Optimization Including all Indices

First, a portfolio optimization is conducted using all ten indices described above in order to identify allocation patterns. When conducting the optimization for the entire sample period without using weight constraints except for no negative weights, a tangency portfolio with a strong bias towards securitized agency mortgages is calculated. The tangency portfolio has 49% weight in the agency CMO index, 24% in the agency MBS index, 18% in the NCREIF TBI index and the remaining 9% in the equity index. Hence, the tangency portfolio, excludes the treasuries and corporate bond indices as well as the REITs. The minimum-variance portfolio has an allocation to the same four indices with direct real estate for 42%, agency MBS for 35%, CMOs for 17% and equities for 6%. The Sharpe Ratio of the tangency portfolio amounts to 1.43 and the percentage of positive days amounts to 85.5%. In chart 12, the efficient portfolios are displayed according to the 20 target returns. It can be observed that at low volatility levels, the NCREIF TBI index is dominant, subsequently the efficient portfolios have a stronger bias towards the CMO and the agency MBS index at returns. At return ranges between 7% and 10% the treasury index has a significant allocation and at the highest target return levels the NAREIT equity REIT index dominates the allocations due to the high return throughout the sample period. This confirms the results of

Brounen, Prado and Verbeek (2010) for higher allocations to indirect real estate in risk tolerant efficient portfolios at the expense of direct real estate.

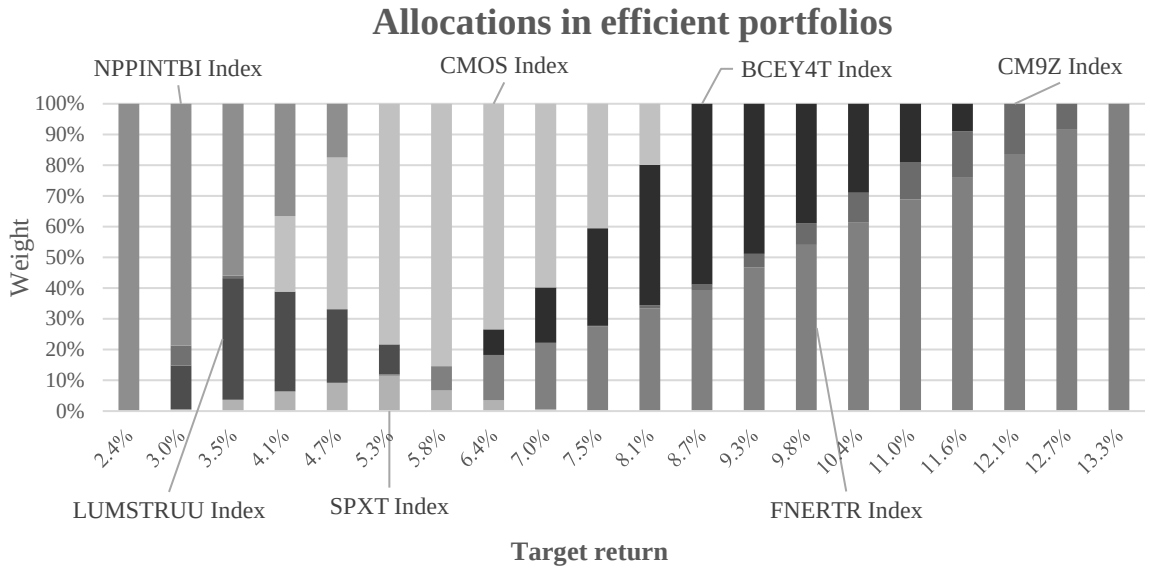

Chart 12: Allocations in efficient portfolios along target returns

In order to assess whether the strong bias towards securitized agency mortgages persists when shortening the sample period, the resulting tangency portfolios are calculated. Chart 13 displays the allocations in the tangency portfolios of sample periods starting in end of March of the years 1999 to 2010 and ranging till end 2016. Several observations can be made when analyzing the resulting tangency portfolios. First, it can be observed, that tangency allocations only consist of the equity index (SPTX), the agency MBS index (LUMSTRUU), the CMO index (CMOS) and the private real estate index (NPPINTBI). Hence, in the optimal portfolios, the securitized agency mortgages fully substitute the traditional fixed income asset class. Secondly, the allocation to securitized agency mortgages (LUMSTRUU and CMOS indices) is relatively stable at between 65% and 70% until the sample start in 2008. Besides, the weight of the CMO index is larger than the weight of the agency MBS index during all sample ranges, signifying that the CMOs offer greater diversification benefits since the agency MBS index has a slightly higher Sharpe Ratio.

This indicates that the bias towards these assets persists throughout the sample ranges until the financial crisis. In line with the findings of Brounen, Prado and Verbeek (2010), allocations to direct real estate range between 20% and 25% in the tangency portfolios, despite the samples starting in 2009 and 2010. In fact, in the sample ranges starting in 2009 and 2010, the optimal allocations gain bias towards private real estate with a 41% and 47% weight respectively in the resulting tangency portfolios at the expense of the MBS index which is excluded. The sample periods that exclude the financial crisis have tangency portfolios with a clear bias towards direct real state and CMOs indicating that the agency MBS segment performed particularly well during the crisis and direct property underperformed in comparison.

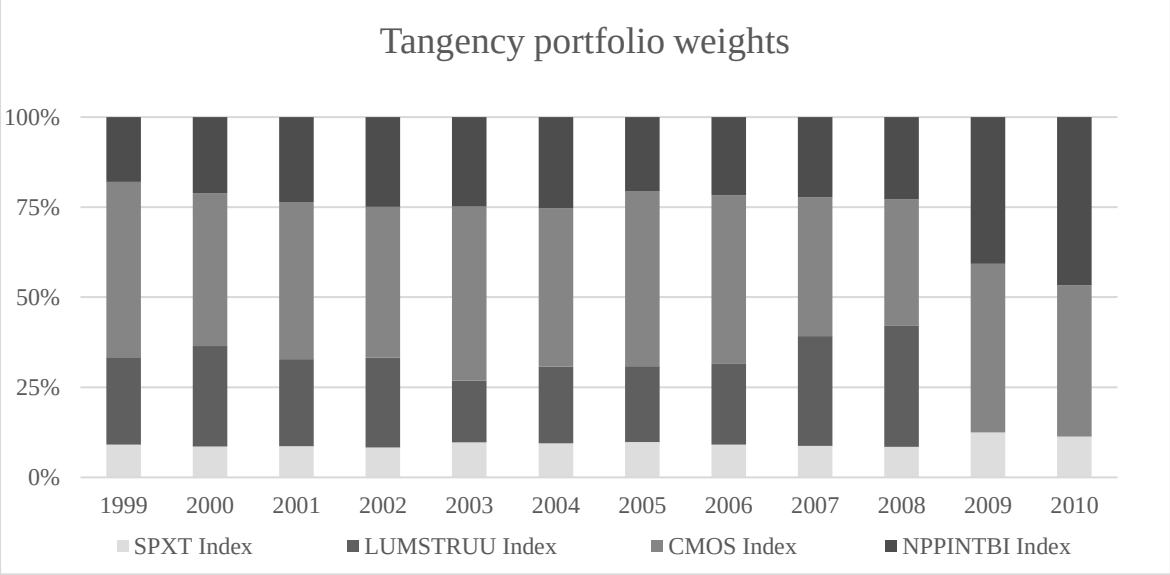

Chart 13: Tangency portfolio weights of samples with different starting points

This analysis confirmed the expectation from the descriptive analysis, that securitized agency mortgages offer both strong diversification potential and have attractive risk/ return attributes. However, in order to calculate weights of optimal allocations in a realistic portfolio that includes the asset classes equities, bonds and real estate, optimizations on several portfolio combinations will be analyzed in the next section.

3.4.2. Scenario Analysis

In this section, portfolio optimizations will be conducted with different portfolio constellations in order to represent different asset mixes. However, the general mix of asset classes, stocks, bonds and mortgages as well as real estate are to be maintained. From the previous descriptive and mean-variance analysis, high allocations of the MBS and the CMO indices in the tangency portfolio are expected due to the high Sharpe Ratios of 1.13 and 1.10 respectively. Since the focus of the tangency portfolio calculation is the maximization of the portfolio Sharpe Ratio, these indices are expected to be prioritized due to their Sharpe Ratios and diversification capabilities. From the portfolio optimizations in the previous section, strong evidence was found for optimal portfolios with allocations to the equity index of around 10%, the private property index around 20% and the remainder in either the agency MBS index or the CMO index. Allocations to the CMBS, CMO Z-tranche and mortgage REITs are not expected due to the findings of the previous section and will thus be excluded from the following analysis.

From the optimization conducted in the previous section, securitized mortgages and direct real estate appeared most attractive for a mean-variance optimization. Hence, the first scenario analyses the allocations of a portfolio consisting of the equity index, the treasury bond index, the agency MBS index and the direct real estate index. First, optimal allocations are calculated throughout the entire sample period, ranging from December 1999 to December 2016 and no weight constraints are set. Setting no minimum or maximum weight constraints entails the risk of excluding an asset class due to unfavorable characteristics under the mean-variance framework. The calculated allocation has a strong overweight in the agency MBS index with 75%, completely replacing the treasuries index and allocating the remainder to private real estate (17%) and equities (8%). The

overweight in the MBS index can be explained by attractive diversification effects and the minimum variance portfolio splits the majority of allocation between the agency MBS (52%) and private real estate treasuries (42%) with the remainder in equities (6%). Hence in the scenario, the treasuries index was excluded in both the GMV and the tangency portfolio. The tangency portfolio achieves an impressive Sharpe Ratio of 1.38 with a return of 4.26% and a standard deviation of 1.79%. Since the over-weighted MBS index has a Sharpe Ratio of 1.10, the difference to the tangency portfolio Sharpe Ratio can be attributed to diversification effects. The tangency portfolio significantly outperforms the calculated equally weighted portfolio, which achieves a Sharpe Ratio of 0.85. Moreover, the equally weighted portfolio is not efficient and has a 26 basis point higher return than the tangency portfolio at the expense of a much higher standard deviation of 3.23%. Chart 14 plots the efficient frontier and the tangency, the minimum variance as well as the equally weighted portfolio.

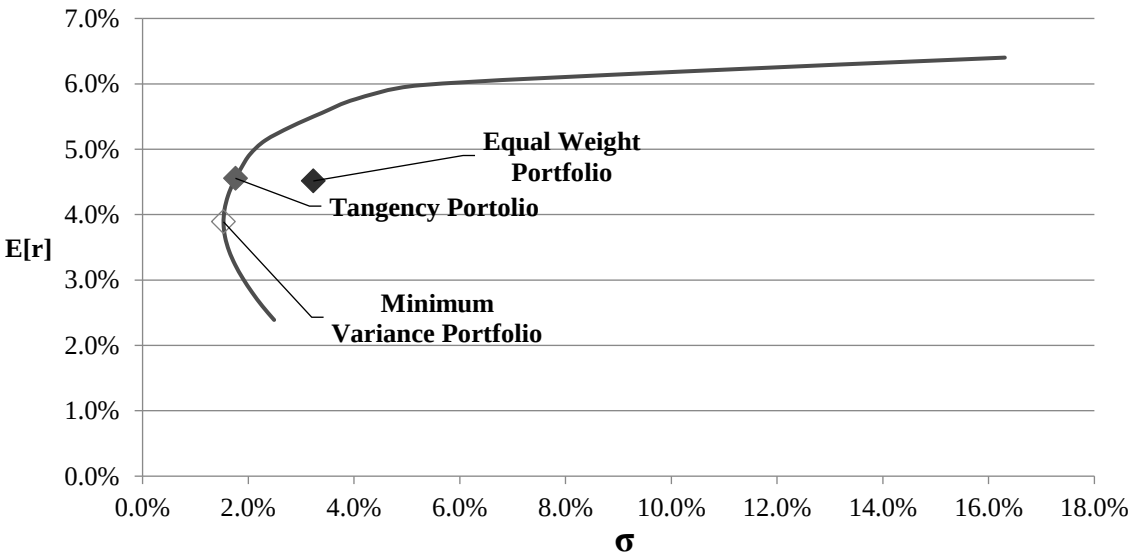

Chart 14: Efficient frontier of unconstrained portfolio consisting of MBS, treasuries, direct real estate and equities

This portfolio would not meet the requirements of a typical investor to invest in a mixed portfolio including fixed income and equity. Thus, a portfolio optimization with the same set of indices is conducted using weight constraints. In order to model the allocation behavior of the MBS index of portfolios with varying biases towards either real estate or equities, multiple optimizations are conducted using different minimum weights in the equity and real estate sector. When placing minimum weights on all four included indices, the allocation continues to be biased towards the MBS index with 65%. When increasing the weight of the equity index, the MBS allocation decreases in line with an increase in allocation to the treasury bills. For example, at equity weights of 20%, 30% and 40%, the agency MBS index has weights of 51%, 15% and 0% respectively. Instead, the remaining weights are allocated to treasuries. This shows a clear inverse relationship and indicates better diversification benefits between equities and treasuries, than equities and agency MBS. When conducting the same experiment, but increasing the weights of the direct real estate index, the opposite allocation behavior can be observed. With increases in the weight of direct real estate, the weight of the agency MBS index maintains the respective maximum weights, while treasuries and equity weights maintain their minimum weights of 10%. This indicates diversification benefits between agency MBS and direct real estate. A similar behavior can be observed when exchanging the agency-MBS index with the CMO index. Hence, the MBS and CMO index are interchangeable since similar allocation behavior was found in this analysis as well as the optimizations conducted in the previous section. For the calculation of an optimized portfolio with a realistic asset mix of equities, treasuries, agency-MBS and direct properties indices, minimum weights of 15% are set for all asset classes, as well as a maximum weight constraint on the MBS index of 40% to limit excessive weights on this index. As expected, the resulting tangency portfolio utilizes the maximum weight for the MBS index of 40%, 24% is allocated to the direct property index, 21% to the treasuries index and the minimum weight of 15% to the equities index.

The return statistics of this portfolio are inferior compared to those from the unconstrained portfolio with Sharpe Ratio of 1.27 compared to the previous 1.38. However, this portfolio continues to outperform the equal weighted and the risk parity portfolios with Sharpe Ratios of 0.85 and 0.71 respectively. It is to be mentioned, that the return statistics of the risk parity portfolio have a smaller sample, starting in end of March 2004, due to the rolling standard deviation calculations. The cumulative performance of the tangency, equal-weight and risk-parity portfolio between end of March 2004 and end December 2016 can be observed in chart 15. It can be observed that the risk-parity portfolio, which distributes the volatility evenly among the included indices, is substantially more volatile than the other portfolios. In fact, the standard deviation of the risk-parity portfolio amounts to 6.60%, versus 2.28% for the tangency and 3.23% for the equally weighted portfolio. This can be explained by the high exposure to equities of this index, since the average allocation to the equity index in the risk-parity portfolio amounts to 56%. Furthermore, a steep decline in course of the financial crisis can be observed, while the tangency portfolio only declines marginally. The total return for an investor would be the highest in the risk-parity portfolio with a return of 91% over the analyzed period compared to the 64% of the equally weighted and 58% of the tangency portfolio. However, a substantially higher volatility needs to be accepted, which reduces the Sharpe Ratio as described above.

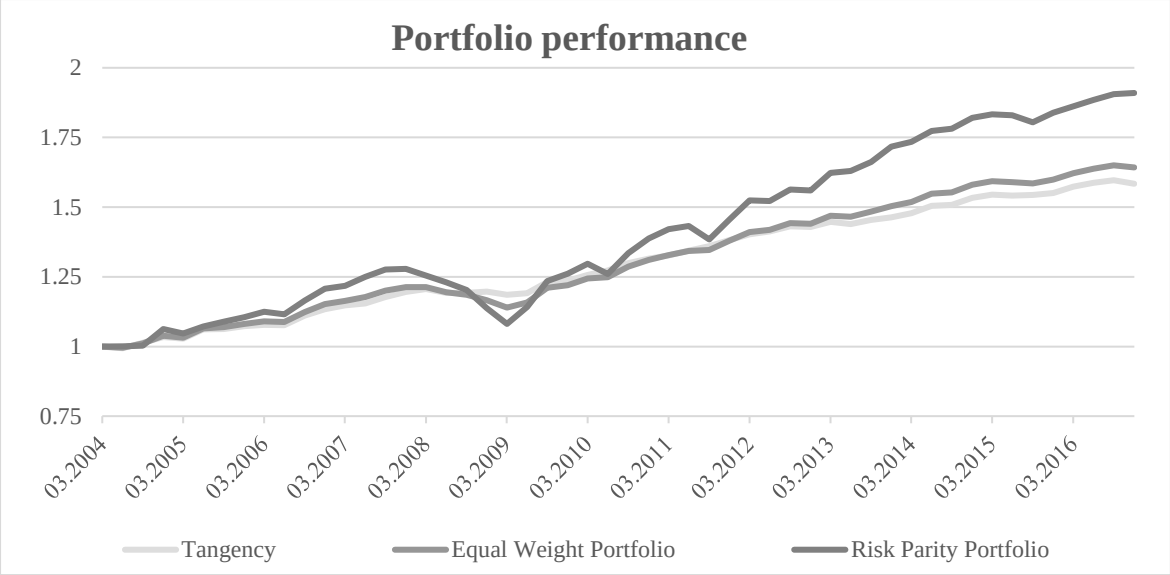

Chart 15: Cumulative performance of tangency portfolio, equally weighted portfolio and risk-parity portfolio

In the second scenario, the NCREIF private real estate index is exchanged with the NAREIT equity index to assess a possible change in optimal allocation. The tangency portfolio of this set of indices creates an even stronger overweight of the MBS index with 90% and the remaining allocation to the equity index. The Sharpe Ratio of this portfolio amounts to 1.36 and is thus higher than the unconstrained portfolio of scenario one. When conducting a similar analysis like in scenario one, a different allocation behavior of securitized mortgages is observable in a portfolio with REITs instead of direct real estate. Similar to the previous analysis, when increasing the weight of the equity index, the weight of the treasuries increases at the expense of the agency- MBS index. However, when increasing the weight of the REIT index, a similar observation can be made. With increasing REIT allocation, the higher the treasury weight and the lower the MBS weight. This observation confirms the findings of the correlation analysis, that the REIT index behaves more similar to equities, and has strong diversification benefits in a portfolio combined with treasuries due to a correlation coefficient of -0.23. However, when forcing constraints in terms of minimum weights on the asset classes in order to limit extreme allocations to MBS and to guarantee a healthy

asset mix and exposure to the equity market, the addition of REITs provides less diversification benefits than the addition of direct real estate in a mixed portfolio of equities, fixed income and MBS. Thus, a constrained version of the portfolio in scenario one is preferable compared to the portfolio of scenario two.

4. Results and Interpretation

The mean-variance analysis found substantial evidence for a significant role of securitized agency mortgages in a diversified portfolio. The descriptive analysis found that the return characteristics of mortgages during the last 18 years are more similar to the those of conventional fixed income securities like treasury bonds and corporate bonds than to real estate investment vehicles. This is expected, since mortgage backed securities are categorized as fixed income securities. Moreover, the securitized mortgage instruments, agency-MBS and agency-CMO indices, achieve the highest Sharpe Ratios of the analyzed indices. The correlation statistics provided an insight into diversification potentials of the of different securities. It was found that, securitized mortgages have a moderate negative correlation to equities and a weak negative correlation to real estate, while having a strong positive correlation to treasuries and corporate bonds. This indication of possible diversification benefits between securitized mortgages and equities as well as real estate could be confirmed in the mean-variance optimization. The mean-variance analysis found securitized agency mortgage instruments to be overweighed consistently in optimal portfolios with weights in excess of 70% for the entire sample. Additionally, the minimum-variance portfolios are overweighed in securitized agency mortgages. However, other securitized mortgage instruments were excluded in the tangency portfolios, like the agency-CMO Z-tranche index and the CMBS index as these securities provided less attractive risk/ return attributes and diversification benefits. Additionally, the unattractive skewness and kurtosis statistics of the agency-CMO Z-tranche index

and the CMBS index create further risk due to extremely fat tales with a high probability of extreme values. The allocations to agency MBS and agency CMOs were on similar levels, however weights of the CMO index were a few percentage points higher than of the MBS index. These observations could be confirmed when shortening the sample size by delaying the sample start. The high allocations to securitized mortgages indicate the attractiveness of securitized mortgage instruments in the mean-variance framework. Although both instruments contain agency- guaranteed conforming mortgages as collateral, structured finance instruments like CMOs are more complex and exposed to higher systematic risk than MBS, as indicated in the study of Coval et al.(2009). However, investments in to special tranches of agency-CMOs, that offer additional protection against changing interest rate environment may be of particular interest in the currently changing interest rate environment. Since securitized agency mortgages focus on a very narrow type of property as collateral, namely owner- occupied housing, the private real estate, represented by the NCREIF transaction based index are a viable addition to a diversified portfolio, as both, residential as well as commercial properties are included in this index. However, the superior diversification benefits that direct real estate provides should be evaluated against the discussed drawbacks of this asset class in terms of lower liquidity, higher transaction costs and higher capital requirements due to indivisibility of direct property investments. Thus, a portfolio resembling the property mix of the NCREIF index may be impossible to replicate. Even if a replication of the portfolio tracked by NCREIF was possible, the discussed information inefficiency of direct real estate may cause a substantially different risk and return patterns than those analyzed. This may lead to different portfolio allocation in the mean-variance framework.

Finally, the analysis found evidence for substantial diversification benefits between direct commercial real estate investments and securitized agency mortgages. When analyzing the drivers

of the agency- mortgages and commercial properties, the following inferences can be made. Commercial property yields appear to be strongly correlated to the 10-year treasury yield as found in section 3.1.2 with coefficients of 0.79 for retail, 0.85 for multifamily and 0.78 for office properties during the analyzed period. Increasing treasury yields lead to a decrease in the spread between the safe treasury bond yield and alternatives like real estate, causing the demand to decline. However, studies found evidence for a questionable relationship of commercial property capitalization rates and the 10-year treasury yield. There is evidence for strongly time-varying correlations between the two rates as well as other factors affecting capitalization rates like credit availability and supply and demand for commercial properties (Mouchakkaa, 2015). Nevertheless, commercial rent increases are usually tied to a benchmark, like the consumer price index, which itself depends on the performance of the economy and thus, to the treasury yields. This also indicates a linear positive relationship of capitalization rates to treasury yields. Since the value of commercial properties depends on the expected future cash flows, the discount rate is a key driver for property values. The discount rate is linked to the capitalization rate as is the inverse of the price/ earnings multiple used in assessing commercial properties. This concludes an inverse relationship between property values and capitalization rates. In section 3.3, evidence was found for this inverse relationship with a correlation coefficient between equity REITs and treasuries of -0.23, which is statistically significant at the 10% level. When assessing the mechanics of the mortgage market, in contrast to commercial real estate, the appreciation of the security plays a subordinate role, as the interest income is the key value driver for MBS. Hence, the spread to treasury yields plays an inferior role compared to real estate. Instead, the focus lies on the coupons of the mortgages, which depend on the treasury yield, indicated with the strong correlations between agency mortgages and treasury bonds in section 3.3. However, the prepayment and extension risk of MBS creates the convexity mechanic, causing weaker price appreciation during

low interest rates due to prepayments and strong depreciation at high interest rates due to extension and duration effects. In conclusion, the diversification effects observed between commercial real estate and securitized mortgages may result from a contrary relationship to treasuries, however there are multiple factors confirming as well as contradicting this behavior. An empirical analysis of this characteristic is out of the scope of this study, but would provide an interesting insight of this observed relationship.

5. Conclusion and Limitations

This study provided valuable insight into the role of securitized mortgages in a diversified portfolio. In the literature review, first the concept of the mean-variance framework was discussed, focusing on theoretical implications of the diversification effect and the most important limitations of this framework, like time-varying correlations as well as excessive weight allocation and the resulting exclusion of other assets. Within the analysis of asset classes, particular focus was set on the differences between direct and indirect real estate and the respective advantages in terms of increased liquidity, diversification potential, information efficiency and lower minimum capital requirements for REITs compared to attractive tax write offs and potential independence from financial markets. Studies confirmed substantial diversification benefits of private real estate, however correlations increased during the financial crisis, decreasing insulation from losses due to market crashes through real estate. The next section discussed mortgage backed securities and highlighted the differences between agency-MBS, non-agency MBS and CMBS in terms of default risk exposure and prepayment characteristics. Moreover, a comparison between MBS and fixed income securities like bonds was provided, stressing, that both instruments have an exposure to interest rate risk, but bond's key pricing determent is default risk, while agency-MBS are only affected by prepayment and extension risk. Subsequently, an overview about structured mortgage

instruments, like CMOs, was provided, which offer the possibility of creating attractive income characteristics through the tranching of MBS cash flows according to investor preferences. In particular the non-agency CMOs contain substantial degrees of systematic risk and contributed significantly to the subprime crisis. In the context of the financial crisis, the incentives and practices of the key stakeholder were discussed, which created perverse incentives to take advantage of short-term gains without taking increased risk measures into consideration. This spiral of increased risk-taking lead to the collapse of the subprime market causing a liquidity squeeze, which in turn affected the wider financial markets leading to the financial crisis. The market analysis demonstrated the collapse of the non-Agency market, but demonstrated the robustness of the agency- MBS market during the last two decades. The mean-variance analysis confirmed, that agency mortgage backed securities have a significant role in a diversified portfolio. The agency-MBS and agency- CMOs were persistently overweighed in the computed tangency portfolios. Even when altering portfolio compositions, agency MBS and CMO weights remained strong.

Hence, this study found considerable evidence for an important role of agency mortgage backed securities in a diversified portfolio, due to excellent diversification benefits and attracter risk/return attributes. The analysis could confirm the first research hypothesis, since securitized agency-MBS have in fact substantial allocations in the computed tangency portfolio with persistent allocations in excess of 70%. This was explained by the high Sharpe Ratios, as well as the strong diversification capabilities of this asset class. In addition to the risk/return attributes, the market analysis indicated a stable performance of this asset class during the last two decades class, making it a valid addition to a mixed investment portfolio. The second hypothesis could also be confirmed since the CMBS and the CMO-Z-tranche index were excluded in most efficient portfolios due to inferior risk/ return statistics. The third hypothesis could partly be confirmed as a significant

distinction between direct and indirect real estate in the mean-variance framework was discovered. REITs, as the highest yielding asset class in this study, have in fact high allocations in the riskiest efficient portfolios. However, direct real estate had significantly lower risk and return attributes leading to higher allocations in the minimum-variance portfolios. Finally, exceptional diversification benefits of securitized agency mortgages in a mixed portfolio in combination with direct real estate was discovered. However, the origin of this effect remains unclear and could be analyzed in a future study. Investors can make use of this study by considering investments into the analyzed asset classes through exchange traded funds (ETFs), which closely track the performance of the underlying index. For example, the agency-MBS index analyzed in this study is tracked by several large ETFs, like the iShares MBS ETF or the Vanguard Mortgage-Backed Securities ETF.

As described in the literature review, the mean-variance optimization framework has substantial limitations. Mean- variance optimized portfolios often lack robustness in out of sample performance, indicating, that the high Sharpe Ratio achieved over the sample period does not last in periods when risk/ return characteristics change. Hence, the results of the mean-variance optimization have to be considered carefully. In particular, concrete calculated allocations should not be assumed without further analysis. This is especially relevant, since this analysis is based on indices representing asset classes. Furthermore, this study ignores transaction costs in the conducted computations, which would have to be paid, due to the quarterly rebalancing required to maintain the calculated tangency weights. Additionally, specific characteristics of direct real estate investments are not considered, in particular the substantial transaction costs due to legal fees as well as the tax benefits realizable through depreciation and mortgage write offs. Finally, the recently announced balance sheet reductions of the FED may lead to declines in MBS purchases,

the absorption capabilities of the MBS market of this circumstance have yet to be assessed. In addition to the diversification effects between direct real estate and agency MBS, an analysis of non-agency- mortgages in the mean-variance framework would be valuable topics for future research. In particular, the analysis of investments into securitized subprime mortgages, would be a noteworthy extension of this study for assessing diversified portfolios with a higher risk exposure. Additionally, the assessment of international MBS may provide a useful insight into geographic diversification effects of securitized mortgages.

6. References

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7. Appendices

Sent in a separate file:

Annex 1: Optimization_model_4_assets.xslm

Annex 2 Optimization_model_10_assets.xslm

Annex 3: Market_data_analysis.xlsx